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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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The Institution of Gas Engineers.
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A SPECIAL GENERAL MEETING of the Institution will be held at the Institution of Civil Engineers, on Thursday and Friday, 17th and 18th October, at 10.30 a.m. each day, for the consideration of the following:—
(1) Preliminary Report of the Gas Investigation Committee. James W. Wood, M.Sc., Research Chemist.
(2) Life of Gas Meters Research Committee's Report: "Unaccounted for Gas," by B. R. Parkinson, M.I.Mech.E.
"The Corrosion of Dry Meters," by J. G. Taplay, Chief Analyst to the Gas Light and Coke Co.
(3) Report of the Refractory Materials Research Committee: "The Corrosive Action of Fine Dust on Fire Bricks," by Walter Emery and Dr. A. Scott, of Stoke-on-Trent. Dr. J. W. Mellor, Reporter.
Forms of proposal for Membership and Studentship from those desiring to join the Institution should be received here by the 16th October.
WALTER T. DUNN, Secretary.
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Further particulars and form of application, which must be returned not later than Monday, 28th October, 1918, will be forwarded on receipt of a stamped addressed foolscap envelope.
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Applications and requests for further information should be addressed to:—
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Wanted, Competent Assistant as Stock-keeper in Engineers' Tool and Supply business, good knowledge of the latter essential. Permanent position, good prospects. No one already employed on Government work will be engaged.—State age, experience and salary to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and M 496. Must be ineligible for military service.

Managing Director Required for Stamped Brass and Metal Manufacturing Company in Birmingham. Must be capable; take entire charge of works. Can invest up to £2000. Good opportunity for right man.—Address, M 304, Offices of ENGINEERING.

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Wanted, a Competent Man, with knowledge of rate fixing and with good experience of modern shop practice to assist in the planning department of a large aircraft firm in North London. No one on Government work or residing more than 10 miles away need apply.—Write, stating full particulars of experience and salary required, to BOX B.M. 6, care of W. H. SMITH AND SON, 55, Fetter Lane, E.C. 4. M 975

Wanted, Competent Man to take charge of small tool room of a Crane Works (controlled). No person already employed on Government work will be engaged.—Apply, stating full particulars in confidence to No. A 6118 at your nearest EMPLOYMENT EXCHANGE. M 984

Technical Engineer Wanted, with first-class mathematical training (B.Sc. preferred). Must have had designing and workshop experience and also some knowledge of estimating. Applicants should state full particulars of qualifications, experience, age, salary required and when at liberty. No one at present engaged on Government work or residing more than 10 miles away need apply.—Address, M 983, Offices of ENGINEERING.

Mechanical Engineer Wanted, who can make inventories of buildings and machinery.—Apply, by letter only, to WHEATLEY KIRK, PRICE & CO., 46, Watling Street, London, E.C. 4, giving experience, salary and references. M 981

Research Chemist Wanted, knowledge of organic chemistry and experience in general metallurgical analysis essential. No one at present engaged on Government work need apply—Apply, stating age, experience, and salary required to your nearest EMPLOYMENT EXCHANGE, quoting No. A 6131. M 997

Engineer Wanted, with Experience of Chemical Plant, to undertake detailed design and general arrangements. One who could control Drawing Office and has good general experience.—State age, salary required, education and experience, to M 880, Offices of ENGINEERING. No one engaged on Government work or resident more than 10 miles away will be employed. M 880

Engineer Wanted, with Good theoretical training; one with experience in Chemical Plant preferred, or with knowledge of Chemistry. Must be a gentleman of good education and appearance. State age, salary required, training and experience. No one engaged on Government work or resident more than 10 miles away will be employed.—Address, M 881, Offices of ENGINEERING.

Engineer Wanted, to take charge of repairs and mainte ance on a Chemical Works in London Applications will only be considered from man discharged H.M. Forces after active service.—Address, stating age, qualifications, experience, etc., M 920, Offices of ENGINEERING.

Junior Inspecting Engineer (age 21 to 26), WANTED by large firm of general engineers in the Midlands, to inspect small iron and steel forgings, malleable and grey iron castings, munitions of war. Must have had previous shop experience. Ineligible for army preferred. No person already on Government work will be engaged. —Apply, giving full particulars, experience, age, salary required, to your nearest EMPLOYMENT EXCHANGE, quoting No. A 6122. M 969

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Draughtsman Wanted, by Controlled Establishment in West Riding of Yorkshire. One with experience in design of motor vehicles.
Also a good JUNIOR DRAUGHTSMAN.
No person already on Government work will be engaged.
Apply in first instance to nearest EMPLOYMENT EXCHANGE, quoting No. 5836, and giving full particulars. M 404

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Draughtsman for Jig and Tool work WANTED by Electrical Engineers (Tyneside). No person already employed on Government work will be engaged.—Apply, stating age, salary and experience, to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and M 854

Draughtsman Wanted, by firm of Engineers in Yorkshire, engaged on high priority work, first-class MAN accustomed to design Electric Jib Cranes, preferably one with experience in handling and conveying plants. No one already on Government work will be engaged.—Apply, stating age, experience and salary required, to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 6108. M 946

Mechanical Draughtsman, with good experience, REQUIRED by Engineers in London. No one already on Government work or residing more than 10 miles away will be engaged.—Give full particulars, age and salary required to M 926, Offices of ENGINEERING.

Draughtsman, Fully Qualified, REQUIRED for Drawing Office of Steelworks; no person at present engaged on Government work will be engaged. Candidates should apply to their nearest EMPLOYMENT EXCHANGE, mentioning No. 6130. M 966

Draughtsmen Required in London. Commercial motor experience preferred. No person already employed on Government work will be engaged.—Reply, stating experience, age and salary required, to your nearest EMPLOYMENT EXCHANGE, mentioning No. A. 6072. M 875

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Wanted, Capable Mechanical DRAUGHTSMAN, must be good Engineer with workshop experience and Technical training for controlled establishment on general work, Manchester district. No person already on Government work will be engaged.—Apply your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5928. M 574

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THE TECHNICS OF MAGNETO-MAGNETS.

By Ellis H. Crapper, B.Eng., M.I.E.E.

The primary function of a magneto-magnet is to provide and maintain, as constant as possible, a storage of energy in the form of a magnetic field in the space between the pole-pieces of a magneto, thereby enabling an efficient electrical ignition system to be developed by the application of the principles of electro-magnetic induction by means of a small generator. The magnet system of a magneto is, therefore, a vital element in the process designed to ignite an explosive charge in the cylinder of an internal-combustion engine by means of the *energy of discharge* of an electric spark, the magnitude of which is—according to the theory of the H.T. magneto—proportional to the square of the maximum value of the magnetic flux traversing the armature core on open circuit.

Now, whilst it is a simple matter to obtain a magnetic flux in the air-gap of the horseshoe permanent magnet, it is generally agreed that the laws and characteristics of the magneto-magnet are not so well defined as those of the electro-magnet associated with the design of an ordinary dynamo, in which magnetically-soft iron, and not magnetically-hard steel, is the material utilised. It is satisfactory to note, however, that for some time considerable thought has been directed to the determination of the relationships existing between the various magnetic quantities involved in the working of magnetos, and to the selection and adoption of reliable values which may be obtained in practice and thus meet the requirements of present-day conditions, and at the same time may be reasonably demanded of the magnet maker.

It is also generally recognised that the magnetic behaviour of magnetisable materials when subjected to magnetising forces is a complex quantity, depending on the chemical constitution, physical condition and form, the previous history and the thermal treatment of the steel during its production. It is probable that few physical phenomena are so complicated and of so variable a nature as those associated with the magnetisation of magnet steel. The complexity is, moreover, accentuated in the case of permanent magnets of the magneto type in consequence of their special shape, which gives full scope to the introduction of irregular strains, whilst the material is being cogged, rolled, bent, hardened, ground and the holes drilled, operations which give rise to lack of uniformity in quality and hardness of the finished magnet.

As is well-known, the solution of many problems in applied magnetism may be readily obtained by assuming similar relationships to those existing in the electric circuit, but it must be pointed out that whilst considerable similarity exists between closed magnetic and electric circuits, there are certain well defined points of dissimilarity between them; thus, the electrical resistivity of a conductor is a *constant* physical property of the material which is not influenced by the current traversing it, provided the temperature remains constant. Magnetic reluctivity, on the other hand, is a *variable* quantity being a function of the magnetic flux traversing it, consequently, the magnetic relationships existing between the magneto-motive-force (M.M.F.), magnetic flux-density, permeability and the energy absorbed by a magnet during the process of magnetisation are simply empirical, and do not conform to simple laws, as is customary in the case of the electric circuit. It is, therefore, necessary to refer the variations in the flux-density B, for different values of the magnetising force H, to a curve, diagram, or table of the values concerned. The well-known hysteresis loop denoting the changes taking place in the values of the flux-density B, for a complete cycle of changes in the magnetising force from $+ H_{max}$ to $- H_{max}$, and from $- H_{max}$ to $+ H_{max}$ is in the form of a cyclic diagram (Fig. 1). When the magnetic tests are made on closed rings of suitable dimensions the cyclic diagram is precise in every respect, and its interpretation gives exact information, whilst, if it refers to a more or less open-circuit test, its indications are somewhat misleading, and should only be accepted, so far as the quality of the material is concerned, when the conditions are clearly specified.

Then, again, both electric and magnetic fluxes are intimately associated with energy; on the one hand, electrical resistance is the cause of dissipation of energy in the form of heat, consequently, the continuous use of electricity requires a continuous expenditure of energy. In the magnetic circuit, however, energy is not required to maintain the existence of a magnetic flux after it has once been established, although an amount of energy equal to $\frac{B^2}{8\pi}$ ergs per cub. cm. is stored up in a magnetic field, so long as the flux exists, and during the process of the initial magnetisation of the material, *i.e.*, whilst it is being taken through a complete cycle of changes in the magnetising forces—a definite amount of energy is absorbed by magnetisable materials, and it is this which enables magnetically-hard steel to retain a definite amount of *remanent* magnetism, and to form *permanent* magnets after a suitable magnetising force has been applied, and then abruptly removed. This remanent magnetic flux indicates a transference

Fig. 1.

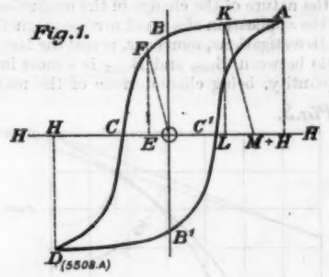
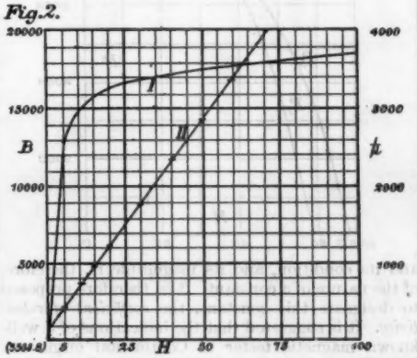


Fig. 2.



of magnetic influence which, in its turn, implies the existence of a *difference of magnetic potential* from point to point of its path, and also impresses one with the fact that a permanent magnet is the *seat* of a certain M.M.F. (magneto-motive-force), rather than of a number of lines of force. This inherent M.M.F. of a permanent magnet is the *cause* of the transfer of magnetic fluxes, both through the metal and through the air-gaps in the case of open-circuit conditions, and the magnitude of the remanent intensity of the flux varies *inversely* as the *reluctance* of the complete circuit. In other words, *a permanent magnet is analogous to an electric battery of constant E.M.F., whose current output is dependent upon the external resistance of the circuit.*

Another point of importance is the fact that an open magnetic circuit is analogous to an uninsulated electric circuit, inasmuch as all known media are capable of transmitting magnetic influences. Permanent magnets are, therefore, surrounded by magnetic conducting media, with the result that it is almost impossible to constrain a given magnetic flux without diminution along a definite path in the case of a partially-open magnetic circuit, consequently, leakage exists to a considerable extent. The one exception to this rule is the completely-closed magnetised annular steel ring of suitable dimensions, in which case the M.M.F. distributes itself, uniformly throughout. With respect to magneto-magnets, the M.M.F. distributes itself proportionately to the reluctances of the separate parts of the composite magnetic circuit, and the magnetic potential gradient varies from section to section—even in the limbs of the magnet—in consequence of leakage from secondary poles due to lack of homogeneity of the material and the existence of holes, cracks and hard spots.

It is thus clear that the magnetic circuit of a magneto-magnet is composed of three portions, *i.e.*, the internal field, in the steel portion, the armature field and the leakage field. Obviously, this leakage portion implies waste of energy; its magnitude depends upon the dimensions and form of the magnet, and, therefore, upon the design of the magnet. In order to keep the leakage field within reasonable limits pole-pieces of good soft iron are introduced, and the air-gaps are made as short as possible, thereby reducing the reluctance of the circuit. Unfortunately, the reluctance of the air-paths of a horseshoe magnet is not so simple or definite as the corresponding element in the electric circuit, and, in many cases, cannot be exactly estimated.

In spite of the many difficulties encountered in the manufacture of magneto-magnets, it is satisfactory to know that the quality of these magnets now produced in this country is of a high standard, and quite superior to the Continental magnets which found a ready market here previous to the war. In the following notes an attempt is made to present an outline of the elementary principles of the technics of magneto-magnets.

The Magnetic Elements of Magneto-Magnets, and their Representation.

The magnetic elements of a permanent magnet which require consideration are the magnetisability of the material, remanence, coercive-force, hysteresis and magnetic rigidity. The relationship existing between the flux-density, magnetising force and the permeability is $\mu = \frac{B}{H}$, but, inasmuch as the permeability is a variable function of the flux-density, it was found impossible to express quantitatively the variations in the values of μ by means of a rational formula, until Lamont, in 1880, introduced the idea of *magnetisability*. Lamont suggested the theory that "the increase of flux-density with increasing magnetising force is proportional to the difference between the *saturation* value (*i.e.*, the maximum possible value) of the flux-density, B_s, and the actual value of the flux-density B corresponding to a given value of H, or algebraically

$$\mu = k\,(B_s - B) \quad . \quad . \quad . \quad (1)$$

The quantity $(B_s - B)$—*i.e.*, the magnitude of the flux-density which the material is still capable of taking up by increasing the magnetising force until complete saturation is obtained—obviously represents the *magnetisability* of the material for the condition under consideration. Thus, Lamont's law states that "*the permeability of a material for a given value of* H *is proportional to the magnetisability of the material*," and *k*, in the formula, is the permeability for unit deficit of the flux-density from the saturation value.

Since

$$\mu = \frac{B}{H},$$

we have

$$\frac{B}{H} = k\,(B_s - B),$$

from which we get

$$B = \frac{k\,H\,B_s}{1 + k\,H} = \frac{H}{\frac{1}{k\,B_s} + \frac{H}{B_s}} \quad . \quad (2)$$

When B is zero,

$$\mu_0 = k\,B_s = \frac{1}{a}\ (say), \quad or \quad \frac{1}{k\,B_s} = a$$

and by denoting the reciprocal of the saturation value of the flux-density by *b*, we get

$$B = \frac{H}{a + b\,H} = \mu\,H$$

and

$$\frac{1}{\mu} = a + b\,H \quad . \quad . \quad . \quad (3)$$

which is the algebraic statement of Frolich's law, introduced in 1882. It gives the relationship existing between the reluctivity (*i.e.*, the reciprocal of the permeability of the material) and the magnetising force as a perfect linear equation, and experience has proved that it agrees exactly with experimental results for ordinary values of H, as indicated by the

straight line in Fig. 2; but it fails at high values of the flux-density, inasmuch as it indicates that at high magnetisations the intensity reaches a limit, which is not the case.

Kennelly, however, has shown that by dividing the total inductivity B into two components, the flux-density contributed by the molecules of the metal and termed the *ferro-magnetic density* or *ferric inductivity*, B_i, may be considered as separate and distinct from that contributed by the ether in the space occupied by the material which may be denoted by B_e. We, therefore, have, as the measure of the ferric reluctivity, $r_i = \frac{H}{B_i}$, whilst for the ether portion B_e increases directly and indefinitely as H increases, or $B_e = H$ in all cases, since the permeability of the ether may be taken as unity, and Kennelly's equation is

$$r_i = \frac{1}{\mu - \mu_e} = \frac{1}{\mu - 1} = a + b\,H \quad . \quad (4)$$

Kennelly's formula is exact within the limits of experimental error, for pure metals and all ranges of H, and it possesses the merit of representing the variations of the *intrinsic reluctivity* of the material directly as the magnetising force varies.

It is a distinct advantage to be able to express numerically the magnetic properties of iron and steel by means of a linear equation, and in Table I. the magnitudes of the constants *a* and *b* are given for widely-different samples of magnet steels. The straight line in Fig. 2 refers to a sample of mild-steel forging used for dynamo magnets, tested by Sir J. A. Ewing, F.R.S., and is typical of the graphical representation of Kennelly's Law. The constant *b* fixes the inclination of the straight line, and is a measure of the tangent of the angle made by the straight line with the H axis, whilst the constant *a* gives the intercept of the line on the vertical or *y* axis, and is the representative value of the initial rate of change in the ordinary magnetisation curve. It thus refers to the physical condition of the material which dominates the reluctivity at the lower magnetising forces. The consideration of the values given in Table I reveals the fact that the constant *a* is characteristic of the *magnetic hardness* of the material, for which reason Steinmetz terms it the *co-efficient of magnetic hardness*. The reciprocal of *a* will, therefore, give an approximate indication of the possible magnitude of the flux-density for a certain applied magnetising force. For hard samples *a* is large, and is small for high permeability materials.

Table I.—*Linear Equations for Different Brands of Steel.*

(*a*) Steel forging for dynamo-magnets
$r_i = 0{\cdot}00071 + 0{\cdot}0000466\ H.$

(*b*) Carbon steel (C = 0·84 per cent.) hardened
$r_i = 0{\cdot}00454 + 0{\cdot}0000572\ H.$

(*c*) Carbon steel (C = 1·21 per cent.) hardened
$r_i = 0{\cdot}0043 + 0{\cdot}0000558\ H.$

(*d*) Tungsten steel (C = 0·59 per cent.; W. = 5·5) not hardened
$r_i = 0{\cdot}00186 + 0{\cdot}0000476\ H.$

(*e*) Tungsten steel (C = 0·59 per cent.; W = 5·5) hardened
$r_i = 0{\cdot}003109 + 0{\cdot}0000612\ H.$

(*f*) Tungsten steel (C = 0·76 per cent.; W = 2·7) hardened
$r_i = 0{\cdot}00423 + 0{\cdot}00005408\ H.$

(*g*) Vanadium steel not hardened
$r_i = 0{\cdot}00132 + 0{\cdot}00005314\ H.$

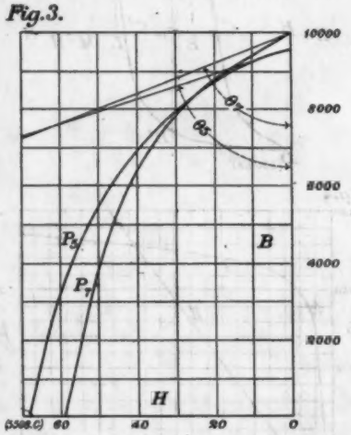
Furthermore, theory indicates that the value of *a* depends upon the elasticity of the material, and it is now recognised that there is a very close connection existing between the magnetic and mechanical properties of a ferro-magnetic material. Thus, the effects produced by annealing and hardening, and by the introduction of strains are clearly indicated by changes in the magnitude of the constant *a*, whilst that of *b* undergoes little or no change.

Many attempts have also been made to determine the relationship existing between the values of the remanent flux-density, B_{rem} (*i.e.*, that measure given by the point in the cyclic diagram at which the descending curve cuts the B — axis) and the maximum flux-density B_{max}, in the form of a linear equation, $B_{rem} = a_1 + b_1\ B_{max}$, but with little success. Remanence is, undoubtedly, an important element in the case of permanent magnets and indicates the normal condition of a finished magnet, so far as the retentive power of the magnet is concerned. An intimate relationship between B_{rem} and B_{max}, however, does exist for a given size, and it is obvious that the character of the curve at the point under consideration, is indicative of the working properties of a permanent magnet, inasmuch as the slope of the curve at this part determines the nature of the change in the magnetisation due to the application of a small reverse magnetising force. Investigations, moreover, reveal the fact that the ratio between B_{rem} and B_{max} is a most important quantity, being characteristic of the material and its condition, and its magnitude is, therefore, of the nature of a constant. It is, therefore proposed to designate this constant, the *coefficient of retentivity*. It is suggested that the indications of a well-known magnetic tester of Continental origin are based upon the values of this constant for different sizes of magnets, and, to a certain extent, the instrument discriminates between good and poor magnets in a fairly satisfactory manner. As a matter of interest it may be noted that the values of the co-efficient of retentivity for magnets of a certain size is of the order 0·65.

TABLE II.—Constants of the Magnet Steels given in Table I.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Sample.	Composition.	B_{max}	B_{rem}	Hc	Ergs of Demagnetisation.	Rigidity Numbers.	E Hysteresis Loss.	η Hysteresis Const.	Square of Susceptibility for H = — 30.	$\frac{1}{K^2}$
		per cent.								
(*b*) ..	C = 0·84	15,025	8,423	58	22,056	2·14	217,000	0·04504	146·0	0·00685
(*c*) ..	C = 1·21	15,621	8,109	53	25,956	2·326	182,000	0·03557	146·0	0·00685
(*d*) ..	C = 0·59 W = 5·5	19,540	11,314	26	16,217	1·0	115,000	0·01568	—	—
(*e*) ..	C = 0·59 W = 5·5	16,103	10,686	73	42,815	2·773	280,000	0·05201	434·0	0·002304
(*f*) ..	C = 0·76 W = 2·7	16,098	10,057	69	41,516	3·412	280,000	0·04831	487·7	0·00205

Fig. 3.



Reference has already been made to the fact that energy is absorbed by steel during the process of magnetisation in consequence of molecular friction, with which is associated magnetic hysteresis, *i.e.*, the *lagging behind* of the magnetisation relatively to the magnetising force. Hysteresis is one of the factors which dominates the form and size of the complete loop of the cyclic diagram, and thus is an element which fixes the position of the remanence point on the B — axis, as well as the intercept made by the curve on the H — axis to the left of the B — axis. This intercept is the measure, in units of H, of the reverse or negative magnetising force which is required to completely remove the remanent magnetism possessed by the sample, for which reason it is termed the coercive-force or coercivity of the material.

The dissipation of the energy involved in the cyclic process of magnetisation demands an expenditure of energy which is derived from the magnetising system, and it may readily be proved that this energy loss, in ergs per cub. cm. of the material per cycle, is given by $\frac{1}{4\pi}$ times the area of the closed hysteresis loop, *i.e.*, by $\frac{1}{4\pi} \times \int H \cdot \delta B$. Steinmetz has shown that E, the energy loss in ergs per cub. cm. per cycle, is given by the relation, $E = \eta B_{max}^{1\cdot6}$, in which η is the Steinmetz *coefficient of hysteresis*. This constant is characteristic of the nature and condition of the material, and several values of η are given in column 8, Table II., for magnet steels.

The remaining element, magnetic rigidity, has in the past, received very little attention at the hands of the engineer, the prevalent idea being that it is a quantity closely associated with—if not a phase of—coercivity. The respective values of these factors, given in Table II, columns 6 and 4, certainly do not indicate any proportional relationship between them, although in some cases there may be some connection between them. From what has already been said, the value of a material for use as permanent magnets may be inferred from the value of B_{rem} considered in conjunction with the character of the slope of the curve at the remanence point, and it is obvious that when the curve approximates to the horizontal at the point of remanence, the more stable and rigid will the material be magnetically, and therefore less liable to the effects of vibration and shock. To obtain the measure of the magnetic rigidity of a magnet, a tangent is drawn to the curve at its intersection with the B — axis, and the rigidity value is given by the intercept on the H — axis made by this tangent. The values given in the table have been obtained in this way.

Furthermore, the nature of the curvature of that portion of the cyclic diagram between the remanence and coercivity points is, from the point of view of investigating the quality of a magnet, more productive of information than any other part of the loop. In the first place, the area enclosed by it and the two axes is the measure of the energy possessed by the magnet in its finished condition when tested as a closed magnetic circuit, inasmuch as the area is proportional to $\int H \cdot \delta B$. This fact has led to the introduction of the principle of taking, as a rough approximation of the *magnetic strength* of a magnet, the product of B_{rem} and H_c. As a discriminating measure, it is a useful criterion in the case of workshop testing, inasmuch as when this product attains the value of 580,000, or a greater magnitude, and the values of B_{rem} and H_c respectively are not less than 10,000 and 55 units, there appears good reason for accepting the magnet. This measure of the magnetic strength, however, does not differentiate satisfactorily between magnets of different dimensions, and it certainly does not correspond to the measures of the rigidity, even when the magnets are of uniform quality.

In order to add to this critical measure of taking the product, $B_{rem} \times H_c$, the suggestion has been made to obtain the magnitude of the intensity of the flux remaining in the magnet after a demagnetising force of H = 30 units has been applied during the test for the coercive force of the magnet. This *apparent* remanent flux is denoted by B^1_{rem} and its measure is given by the ordinate in Fig. 3 for H = — 30. The merit of this additional measure lies in the fact that the greater ordinate for two magnets, with equal values of B_{rem} and H_c, will have the flatter curve at this point, which is a valuable criterion when comparing two magnets. But in the case of two magnets of equal product, but differing in the values of B_{rem} and H_c, the greater ordinate is not necessarily a measure of the operating or working quality of a magnet. A better criterion is to take the value of the *apparent co-efficient of*

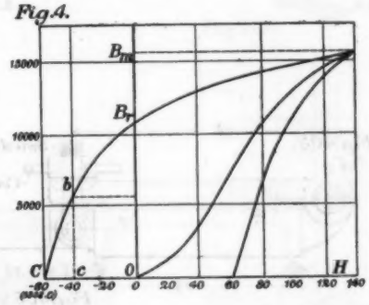
retentivity, given by the ratio $\frac{B^1_{rem}}{B_{rem}}$. Probably, also, the value of $H = -30$ does not give the most suitable point of reference, and the value of $H = -20$ is put forward tentatively, inasmuch as the falling off in the flux-density of a newly-magnetised magnet down to its steady or constant intensity is something of the order of 33⅓ per cent. of the *real* remanence, as obtained by a closed circuit test. The reason why the value of B^1_{rem} is not necessarily an exact criterion is the fact that it does not indicate the slope of the curve at the point under consideration. What is really wanted is a measure of the square of the magnetic *susceptibility*, K, of the material at the point, according to the law "the rate of variation of magnetisation, with changes in the magnetising force, is proportional to the square of the magnetic susceptibility," or $\frac{\delta I}{\delta H} = c\left(\frac{I^2}{H^2}\right)$. From this point of view the more satisfactory the magnet the smaller will be the value of K^2, or, better still, the larger will be the value of $\frac{I}{K^2}$.

It is difficult to explain why there may be a difference in the nature of the gradient in the curve between the remanence and coercivity points in the case of magnets which have identical values of B_{rem} and H_c. One would expect a more rapid variation in the flux-density during demagnetisation, on the one hand, in the case where two magnets have the same product, but different values of coercivity, inasmuch as the areas enclosed, and, therefore, the energy represented, would approximate to equality, provided the measure of the *magnetic strength* was representative of the value of the magnet as fixed by the area. The difference in the rate of change in the intensities may possibly be due to the difference in the elastic properties of the material, since there is some evidence, which indicates that the constant c in the equation $\frac{\delta I}{\delta H} = c\left(\frac{I^2}{H^2}\right)$ is associated with the measure of the elastic limit of the material. This matter can only be decided by research: but it is suggested that whatever changes take place in a magnet, in consequence of external influences, occur because the elastic limit of the material is such as permits the movement of the molecules of the magnet to take place slowly or quickly as the case may be. Both physicists and chemists are unanimous that the magnetic and mechanical properties of a material depend upon the *structural constitution* of the material, rather than upon the chemical composition, and from this point of view it appears that the variations in the slope of the curves is due to variations in the heat treatment of the magnets, even if slight, and, therefore, to differences in the magnitudes of the elastic properties.

The two properties, high permeability and relatively large remanent intensity go together, and are as a general rule, associated with a low value of coercivity, from which it may be implied that steels which develop large values of magnetomotive force per unit volume when magnetised, do so more or less weakly, and soon decay, thus denoting low permanence. If such materials are employed for making permanent magnets, the only advantage they possess is their small volume and light weight. The requisite and vital property in magneto-magnets is high coercivity, which is indicative of great permanence and probably a large magnetic rigidity; but high values of coercivity and permanence are generally associated with lower values of remanent intensity and permeability. Magnets made of materials possessing the latter qualities retain from 5,000 to 8,000 lines per sq. cm. of cross-section, and are, consequently, bulky and heavy in order to secure the necessary M.M.F. and requisite flux. This implies that the question of composition must be taken into account when the suitability of a magnet for a given function and its cost have to be considered, and in some cases simple carbon steels suffice. Thus, in the case of permanent magnets in the form of long, thin, straight rods, or of a nearly-closed ring or of a horse-shoe with a very narrow gap, a comparatively low carbon-content steel (*i.e.*, O = 0·5 per cent.) will suffice, inasmuch as high remanence is essential, whilst the coercive force is of secondary importance, the demagnetising effects of the ends being relatively small. On the other hand, a high percentage of carbon, or the addition of tungsten, chromium, vanadium or molybdenum is essential when the magnets are in the form of short, stout rods or a horse-shoe with a broad pole-gap, in order to secure a large coercive-force, and thus keep the demagnetising effects of the ends within reasonable limits.

At the present time the want of a complete specification is keenly felt by all concerned, and it is suggested that the factors α (Kennelly's Law), retentivity co-efficient, magnetic rigidity, η (Steinmetz's co-efficient), in addition to the usual values of $B_{max.}$ B_{rem} and H_c should be considered when deciding upon the quality of the material for use as magneto-magnets, the results being obtained from standard ballistic tests on the material in the form of bars. Whilst in the case of the more practical or workshop tests, the values B_{max} B_{rem}, H_c, co-efficient of retentivity, and the values of $\frac{I}{K^2}$ for a specified magnitude of the demagnetising force, should be obtained, and there appears to be no difficulty in devising a magnetic tester which will permit the necessary values to be obtained readily and quickly, even when the conditions of the test approximate to the working arrangements of a magneto.

Fig 4.



Elements of Design.

When one comes to the design of permanent magnets for specific service, it is obvious that the dimensions and shape are factors, as well as the remanent intensity, which have to be taken into account to obtain the requisite working conditions. The following is a brief outline of the general principles underlying the design of permanent magnets.

When selecting the material, it will be assumed that samples of different steels, in the form of straight bars or closed rings, are suitably wound with primary and secondary windings, and the magnetic properties determined ballistically after the material has been hardened to the right degree, and that curves have been obtained similar to the half-hysteresis loop shown in Fig. 4. After magnetising the sample to a maximum induction-density, B_{max}, the magnetising force H is gradually reduced to the zero value, and O B_r represents the remanent intensity, corresponding to which the coercive force is O C for the closed-circuit condition. O C is, therefore, a measure of the M.M.F. per cm. length of the magnet, in the case of the ideal closed magnetic circuit. Obviously, the object sought in designing a magnet is to secure as large a value of the flux-density as possible, consistent with permanence; but inasmuch as an air-gap forms part of the magnetic circuit of the magnet in practically all cases for which permanent magnets are required, it follows that the conditions represented in Fig. 4 are more or less modified in the case of composite magnetic circuits—*i.e.*, magnetic circuits partly steel, iron and air. Thus, if we imagine that a saw-cut (introducing an air-gap) be made through the steel ring, it is obvious that only a portion of the total M.M.F., represented by the coercive force O C, will now be available for sending the flux or lines through the steel portion; consequently, the flux-density in the steel will be less than that denoted by O B_r. And since the reluctivity of air is μ times that of the ferric portion, it follows that the difference of magnetic potential, V_s reserved for the steel portion, will be small compared with the difference of magnetic potential V_g required for the air-gap, when the air-gap becomes appreciable in length. In all cases we have—

$$\text{total M.M.F.} = V_s + V_g,$$

and, considering the problem as analogous to a composite electric circuit, we may assume that the M.M.F. provided by the magnetised steel is distributed proportionately to the reluctances of the several portions of the complete magnetic circuit. To take a specific example, we may suppose that with a certain length of air-gap, l_g, the difference of magnetic potential V_g required to send the desired flux across the gap is denoted by O c, when the total M.M.F. of the magnet is represented by O C; then C c denotes the difference of magnetic potential, V_s expended on the metal portion of the circuit, and the flux-density in this part of the circuit will be given by the ordinate b c. To determine the dimensions of a permanent magnet which will give a definite flux in an air-gap of given length, it is essential that the curve for the material similar to that given in Fig. 4 should be obtained. In order to secure permanence, it has been found that a flux-density of 2,000 lines to 3,000 lines per sq. cm. gives satisfactory results, and when this value has been decided upon, the required value of the difference of magnetic potential V_s required in the steel is given by the length C c. Now, since the gap difference of magnetic potential per cm. length 0·8 B_g, where B_g is the flux-density in the air-gap, it is possible to calculate the magnitude of B_g for given values of l_s and l_g, from which the area of the cross-section of the gap is obtained for the flux required. Usual values of B_g lie between 800 lines and 2,000 lines per sq. cm. When the difference of magnetic potential V_g required for a given air-gap is known, the required length of the magnet is given by $\frac{V_g}{O\,c}$. Allowance, however, must be made for leakage, ageing loss, &c., and it is usual in practice to increase the estimated area and length of the magnet by 10 per cent. For permanence, Hookham found that the following empirical formula respecting the relationship between the dimensions of the magnet and air-gap gives good results in practice—

$$\frac{A_g}{l_g} = 70\,\frac{A_s}{l_s}$$

where A_s and A_g denote the magnet and air-gap areas, and l_g and l_s the lengths of the gap and magnet respectively, so that when $A_g = A_s$, the length of the magnet should be 70 times that of the air-gap. This relationship is based upon the fact that the internal reluctance of the magnetic circuit is equal to the external reluctance, and a factor of safety of approximately three, is allowed—*i.e.*, the magnetising force is then approximately three times that of the demagnetising force.

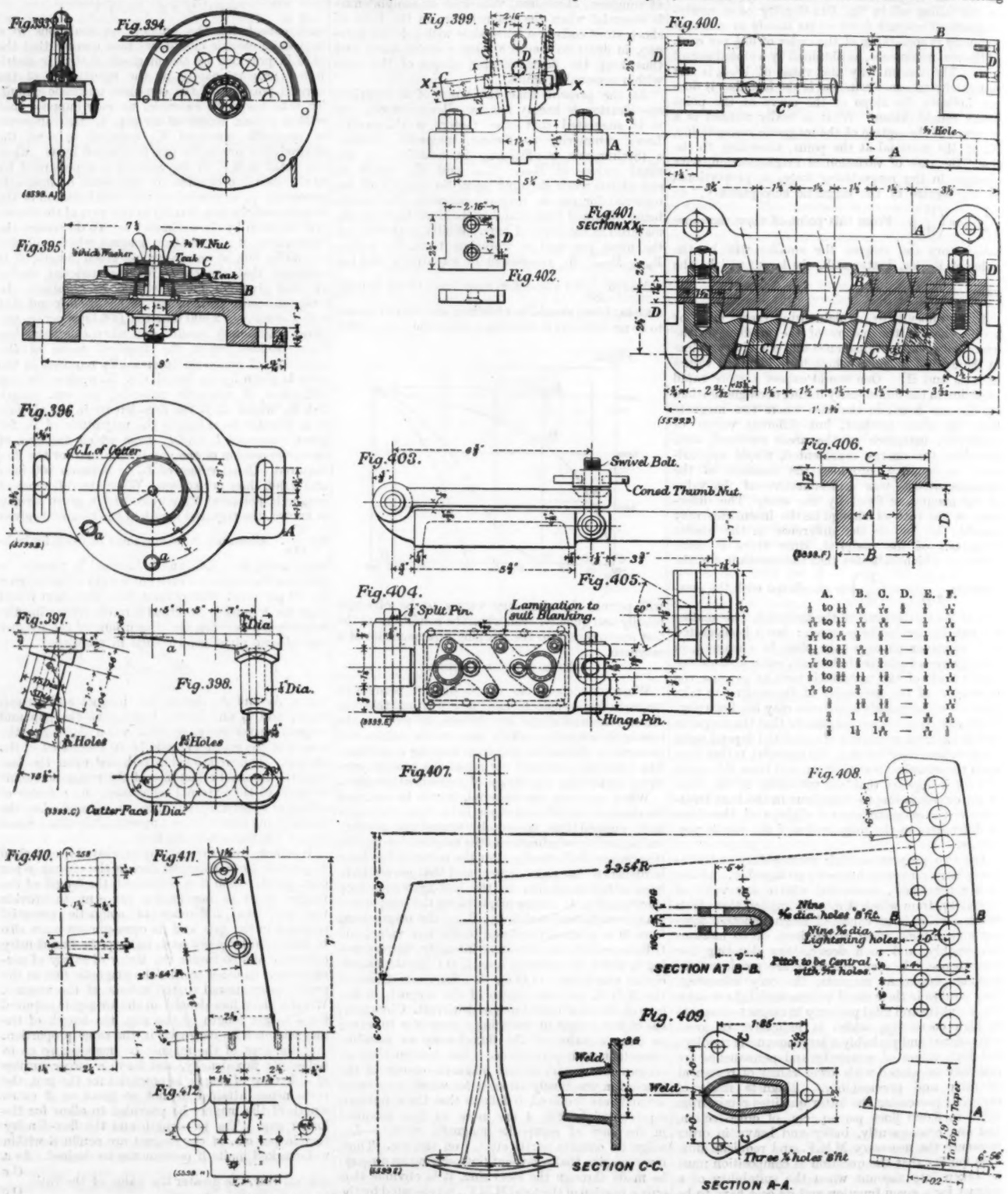
It follows from first principles, that if it is desired to provide for a magnetic flux in the air-gap p per cent. greater than that estimated, the length of the magnet must be increased p per cent. to provide the additional difference of magnetic potential required in the gap, and its cross-section must also be increased by p per cent. to keep the flux-density constant, and so insure the factor of safety of permanence. In other words, the magnetic flux in the gap is proportional to the volume of the magnet. When a given flux-density in the air-gap is required for a longer length of the gap, the length of the magnet must be increased in the same proportion.

If the area of the magnet be increased so as to reduce its flux-density, and leave a larger surplus of difference of magnetic potential for the gap, the permanence attained is not so great as if extra length of the magnet be provided to allow for the longer gap. The gap-length and the flux-density therein per cm. of the magnet are confined within well-marked limits if permanence be desired. As a general rule, the greater the value of the ratio $\frac{C\,c}{O\,c}$ (Fig. 4)—*i.e.*, the greater the proportion of the M.M.F., expended in the steel, the more permanent the magnet; hence the working rule that "the polar area at the gap should be as large, and the gap-length as small, as possible."

TEMPLETS, JIGS AND FIXTURES.
No. XIII.

By Joseph Horner.

Some miscellaneous examples of fixtures and jigs are given in this article culled from the practice of three leading firms. The illustrations on the present page are concerned with the work on some aeroplane parts as carried out by Messrs. Ransomes, Sims and Jefferies, Limited, of Ipswich. The first example is that of a fixture in which the half of a pulley casing is held while a groove for the control wire is being milled. The pulley in its casing, with the control wire, is seen in Figs. 393 and 394: the only detail which concerns the present subject is the groove in the casing. The fixture is shown by Figs. 395 and 396. It includes a base A, of cast-iron, which is common to all the different sizes of pulleys dealt with, on which baseplates of teak B are fitted to suit each size of pulley made. The teak disc is recessed to take a half-casing C, which is secured with a smaller disc, and centred, and tightened with a bolt and wing nut. A flange on the bolt centres the bottom disc, Fig. 395, and is fastened to it with six wood screws. The setting to the angle of the groove is done with a pin entering holes seen in Fig. 396. As the angles vary in pulleys of different sizes these variations are provided for in the plates, for which a table is given. The holes in the recessed teak plate B are bushed



A.	B.	C.	D.	E.	F.
½ to ¾	⅞	⅞	⅝	½	⅞
⅞ to 1	⅞	⅞	—	½	⅞
1⅛ to 1¼	1	1	—	½	⅞
1⅜ to 1½	1⅛	1⅛	—	½	⅞
1⅝ to 1¾	1¼	1¼	—	½	⅞
1⅞ to 2	1⅜	1⅜	—	½	⅞
2⅛ to 2¼	1½	1½	—	½	⅞
2⅜ to	1⅝	1⅝	—	½	⅞
2½	1¾	1¾	—	½	⅞
2⅝	1⅞	1⅞	—	½	1
2¾	2	2	—	½	1
2⅞	2⅛	2⅛	—	½	1
3	2¼	2¼	—	½	1

Figs. 393 to 412. Fixtures by Messrs. Ransomes, Sims and Jefferies, Limited, Ipswich.

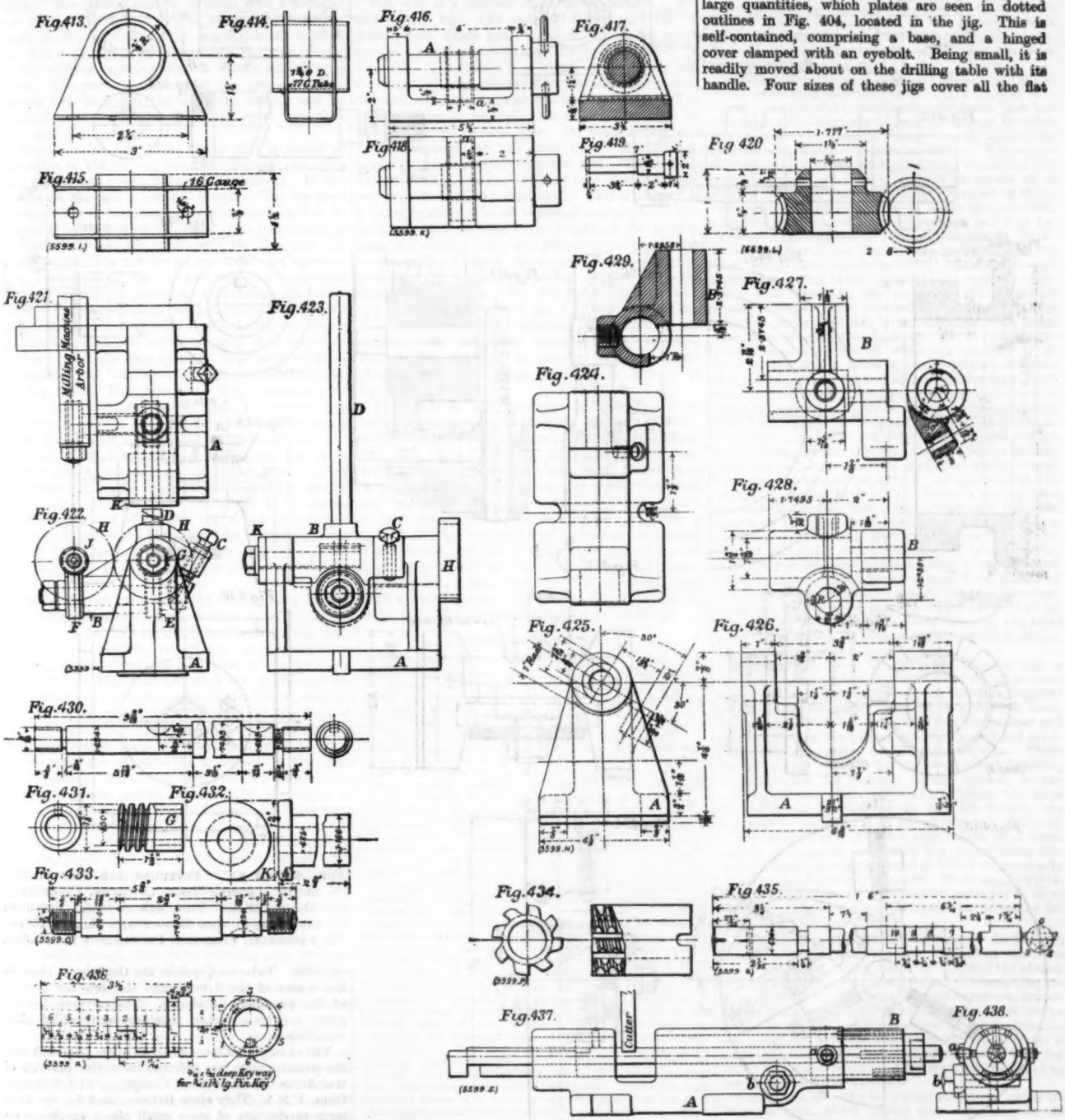
to receive the pins that pass through to enter holes in the cast-iron bottom plate. One set of holes is on the centre line at right angles with the axis of the plate bolted to the machine table.

The next example is that of a fixture for holding flap pulley brackets, Figs. 397 and 398, to have the tops of the feet milled. These are right and left-handed, and are held in opposite sides of the fixture, four of each hand being treated at one time.

It will be observed that the face *a* of the foot lies in two angles in relation to the stem, one in the longitudinal, Fig. 398, the other, Fig. 397, in the transverse direction. These are provided for in the fixture, Figs. 399 to 401, which comprises a foot A to bolt to the machine table, and a central vertical portion B, in the faces of which recesses are cut to receive the feet of the brackets. In the sectional plan, Fig. 401, the angles of the recesses correspond with the transverse angle at the left-hand view of the bracket in Fig. 397. In the end elevation, Fig. 399, the angles are seen to correspond with the longitudinal angle, Fig. 398. A bracket is seen outlined on the left-hand of Fig. 399, A bracket is also shown by dotted lines in the side elevation, Fig. 400. The brackets thus lie snugly in the fixture by the whole length of their feet, the undersides of which have been previously tooled in a fixture of a similar design. They are supported in addition in a loose strip C, which has holes bored to receive and steady them, which strip fits in a longitudinal groove, and is clamped to the main body of the fixture with a bolt at each end, and a clamping plate, Fig. 401. These details are seen as arranged for tooling four brackets on one side of the fixture, after which four of the other hand are dealt with on the side opposite. At each end of the main fixture, a gauge plate D is screwed as a guide to set the cutters by laterally, and depthwise by the shoulders (compare with the separate detail, Fig. 402), for tooling the bevelled top of the foot.

The illustrations, Figs. 403 to 405, relate to a master jig used for drilling flat plates required in large quantities, which plates are seen in dotted outlines in Fig. 404, located in the jig. This is self-contained, comprising a base, and a hinged cover clamped with an eyebolt. Being small, it is readily moved about on the drilling table with its handle. Four sizes of these jigs cover all the flat plates that have to be drilled, and large numbers of each size are distributed about the shop. The bottoms or base portions are machined in quantities, but the top hinged member is thicknessed to suit the gauge of the plates to be drilled. These are located by their edges which enter into recesses cut in the edges of the strips riveted on the base. Bushes, Fig. 406, are inserted in the hinged cover. They are standardised in a number of sizes, the dimensions of which are given in the table.

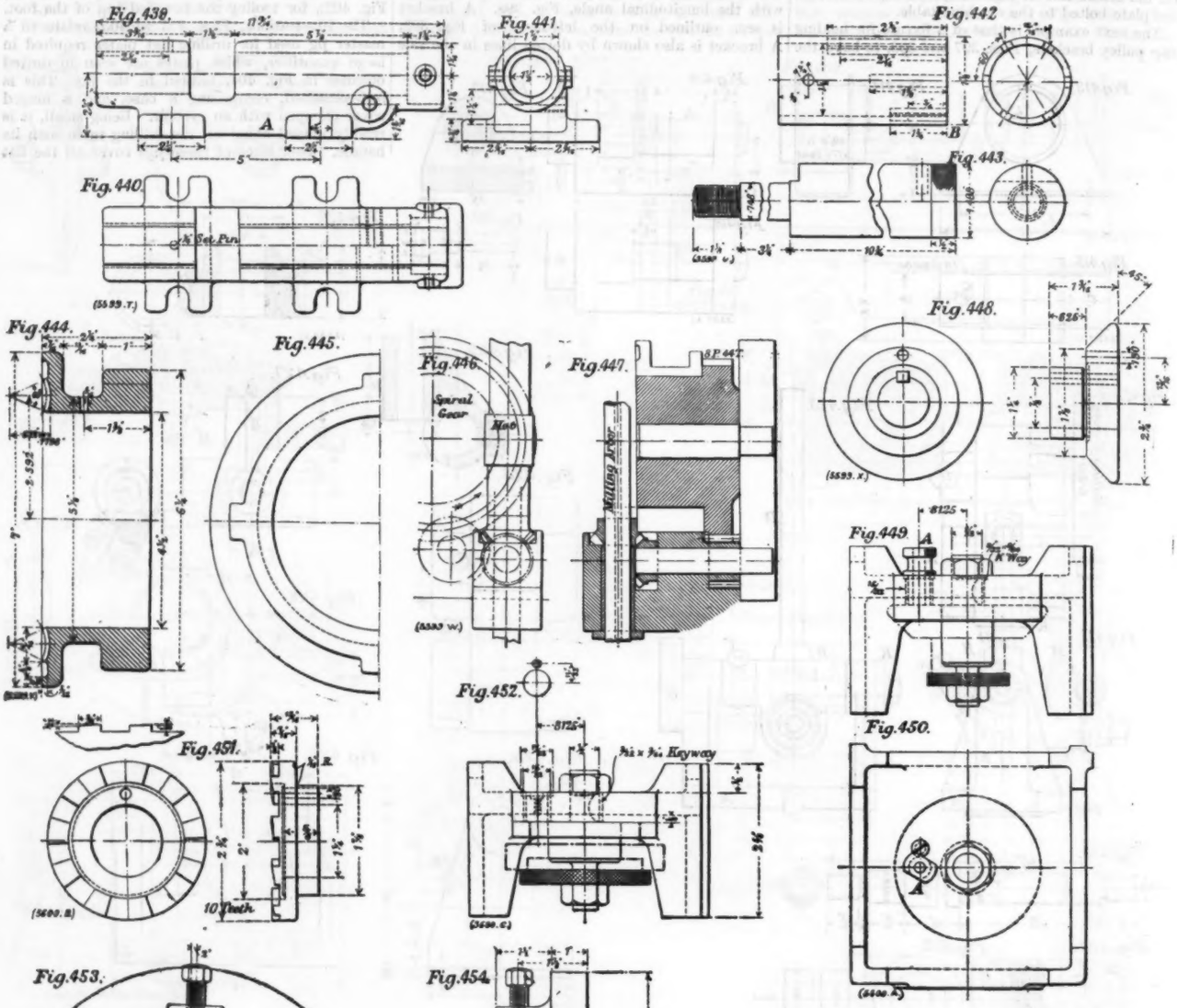
A fixture of another class is used for locating parts to be welded. Figs. 407 and 408 show a tail



FIGS. 413 TO 419. WELDING FIXTURE BY MESSRS. RANSOMES, SIMS AND JEFFERIES, LIMITED, IPSWICH. FIGS. 420 TO 438. FIXTURES AND JIGS BY THE ACME MACHINE TOOL COMPANY, CINCINNATI, OHIO, U.S.A.

plane adjusting bracket, its sections being seen in the group, Fig. 409. The foot of this has to be welded to the upright in correct relationship after then tacked together, and the weld is finished after removal.

Another welding fixture is used for setting a tube first located in the central slot *a* prepared for it in the base of the fixture. The tubular part is pushed on the spindle A, until stopped by the



shoulder. Tube and spindle are then thrust through the bosses of the fixture, and the bracket portion of the pressing, as shown. The correctly-located parts are then tacked together, and welded after withdrawal.

The examples, Figs. 420 to 447, on page 365 and the present page, are selected from the practice of the Acme Machine Tool Company, of Cincinnati, Ohio, U.S.A. They show fixtures used for the very large production of some small pieces employed on the firm's machines, in which an obviously simple bit of tooling involves elaborate preparations to secure interchangeability of thousands of pieces.

Fig. 420 shows a small worm wheel, the teeth of which have to be cut on a Pratt and Whitney hand-milling machine. It measures only 1.717 in. over the points of the teeth—25 in number, 0.1373 in. deep. These wheels are made both left and right-handed, single-threaded. A general view of the fixture used is shown by Figs. 421 to 423, and some separated details in subsequent views. A main bracket A is recessed to receive a hinged work-holder B, the exact location of which is set and all the holes have been drilled, the setting for which is done in the fixture, Figs. 410 to 412. The upright is attached to the two bosses A, A, and the foot is fastened to the base portion. The two are for a pressed control cross-shaft bearing. The completed article is seen in Figs. 413 to 415, on page 365, and the fixture in Figs. 416 to 419, on the same page. The bracket portion of the pressing is

Figs. 439 to 447. Fixtures and Jigs by the Acme Machine Tool Company, Cincinnati, Ohio, U.S.A. Figs. 448 to 455. Fixtures and Jigs by the Brown and Sharpe Manufacturing Company, Providence R.I., U.S.A.

arrested by a stop and stop-pin C, when the work-holding spindle occupies a horizontal position, and which is moved about with the long handle D. The work-holder receives an arbor that carries a master worm gear E, of mild steel, carbonised, of the same dimensions as the gear blank F to be cut, the latter being mounted at the opposite end of the arbor. The master gear is in mesh with a worm G the shaft of which is driven through equal spur gears H, H, from the arbor on which the cutting hob J is mounted. The arbor fits into the spindle of the milling machine with a Brown and Sharpe taper. The parts are shown in the group of Figs. 424 to 434, in which the separate details can be understood better than in the general assembly drawings just referred to.

The main bracket, Figs. 424 to 426, is bolted to the table of the milling machine through two open slot holes, for ready fixing and removal. It fits to the table with a central tongue. The recessed portion affords clearance for the work-holder B, Figs. 427 to 429, which by means of its long handle D is thrown downwards sufficiently far to enable the blank to clear the hob for its insertion, and removal. The front part of the concave recess is chamfered away, Fig. 422, to permit of this downward movement. On its return to the horizontal position the screwed stop-pin C provided with a lock nut comes in contact with the hardened stop that is driven into a hole in the base casting. The work-holder is pivoted in the base on a long pin, shown in detail in Fig. 430. The worm G, seen separately in Fig. 431, is mounted on this pin. It is inserted in the larger hole in the base bracket, which hole is then closed with a bush K, Figs. 421 and 423, and, separately in Fig. 432. A collar on the bush determines its position against the bracket, and the opposite end of the bush abuts against the end of the worm. One of the equal gears H, is keyed on the other end of the pin, and a nut at each end secures the pin in the bracket. The enlarged portion of the bore, and the screwed boss that receives the handle D are seen in the section of the work-holder in Fig. 429.

In the lower portion of the work-holder B, the worm-wheel blank and the master worm wheel are carried on an arbor, which is shown in Fig. 433. The central portion, where the largest diameter occurs, occupies the long boss seen in Fig. 422, and in section in Fig. 429. At each end of the pin the diameters are reduced to receive the blank, and the master worm wheel, with threaded lengths beyond for the nuts. Fig. 434 shows a hob used for cutting the gear, being made right and left-handed.

An example of indexing is shown in the next illustrations. Figs. 435 and 436 are stop index pins, that are milled transversely at angles of 120 deg. and 60 deg. and to definite distances from the ends. These, as most lathe men know, are leading elements in the unique system of stops that is employed in the Acme turret lathes. The scheme of the fixtures designed for tooling both these elements is shown by Figs. 437 and 438, page 365. The body A, bolted to the table of the machine, and shown in its three views in Figs. 439 to 441, is bored to receive bushings B (compare with, Fig. 442) through which the indexing pegs, the grub screws *a*, *a*, Figs. 437 and 438, are put. The bush shown has six slots, which are cut to definite lengths that correspond with the longitudinal distances of the sections to be milled. A set screw *b* grips the bush securely in the body though the medium of a loose block. The stop index pins to be milled are carried on a holder, Fig. 443, this being designed for the pin in Fig. 436. The right-hand end makes a slide fit in the bore of the body A, Figs. 437 and 440, and in the bush. The stem at the left-hand end carries the feed-stop index, which is secured with a clamp nut. For the mounting in Fig. 437 the holder is bored to receive the auxiliary stop index of Fig. 435.

A face gear used on the lathes of the Acme Company has spiral (hyperboloid) teeth produced by hobbing, Figs. 444 and 445. The fixture used is shown by Figs. 446 and 447, mounted on the machine. It is provided with a spur gear of 44 teeth, driven by a pinion, so rotating the blank. The milling arbor, driven through mitre gears, rotates the hob.

On page 366 are shown some fixtures and jigs as made by the Brown and Sharpe Manufacturing Company, of Providence, R.I., U.S.A. Although the only work done in them is a little drilling and reaming, the numbers of units turned out are large, and the designs provide for quantity production, with wear long delayed.

Fig. 448 is a driving shaft clutch holder. The fixture jig, Figs. 449 and 450, provides only for drilling one small hole, 0.190 in. in diameter, to receive a pin that locates it relatively to its clutch, in Fig. 451. The fixture is a square casting, with feet standing up high enough to permit the casting attached beneath to clear the machine table. The clutch holder is secured with a bolt, the body of which fills the central hole. Its washer below is slotted through on one side to be slipped out laterally, without removing the nut. The hole is drilled through a bushing A, of tool steel hardened and provided with a milled head. This is inserted in a lining bushing, also of hardened tool steel, so that both are very durable. The length of the drilling bush also delays wear, and affords perfect guidance to the drill. A small cheese-head screw, Fig. 450, prevents the bush from being revolved by the friction of the drill. Fig. 451 is the clutch, which also is furnished with a jig, Fig. 452, for drilling the small hole. It resembles the other in its outlines, and the same remarks apply to each. The drilling bushing is exactly like the other, though only the lining bushing is shown in Fig. 452.

Figs. 453 to 455 illustrate a fixture used for drilling and reaming the bore of a slotting cam lever, which is shown in dotted outline in the plan view, Fig. 453. It is located on the centre of the plate with three set screws, case-hardened. The casting is supported on the heads of studs, hardened, and driven into the plate, seen in each view, and it is held down with a single clamp. This also is provided with a hardened stud to bear on the casting. The clamp is supported at the other end on a stud, entering a groove on the under side of the clamp that prevents it from turning. The bolt is encircled with a coiled spring, that throws the clamp off the work when the pressure of the nut is taken off.

"The American Journal of Science."—The July issue of *The American Journal of Science*, which used to be known as *Silliman's Journal*, commemorates the 100th anniversary of the founding of the journal by Benjamin Silliman in July, 1818. The issue of 416 pages contains a sketch of the history of the journal and 11 chapters on the development of those branches of natural science to which the journal has particularly been devoted throughout its existence. Prominent among these is zoology in its various aspects; mineralogy, botany, geology, chemistry and physics are chiefly treated in their bearing on geological problems, and there is a special brief chapter by R. B. Sosman on the work of the Geophysical Laboratory of the Carnegie Institution at Washington. The problems of rock production, Sosman points out, can be approached by three methods: (1) By reproducing in the laboratory some of the changes observed in natural rocks; (2) by applying the principles of physical chemistry to a great body of carefully selected statistics; (3) by bringing together pure materials under measurable conditions thus to establish by strictly quantitative methods the conditions in which minerals can exist together at temperatures and pressures which have power to affect such relations. This third method has chiefly been used in the Geophysical Laboratory since its foundation in 1905, and it has proved practical not only to make quantitative studies, over a wide range of temperatures, of the relations existing between the principal earth-forming oxides (of silicon, aluminium, calcium, the alkalis, iron), but also to extend these studies to copper sulphide, silicates and glass. It has further been shown, according to Sosman, that rock formation in which volatile ingredients play a determining part, can be studied in the laboratory with as much precision as if all the constituents were solids or liquids. These are high claims; there is a natural apprehension that the vast ramifications and complications of rock formation cannot adequately be investigated in the laboratory, and we are not so certain that this apprehension has really been dissipated. But the Geophysical Laboratory has certainly done excellent work, particularly also with respect to volcanic action which its emissaries have been exploring on Vesuvius, Etna, and Stromboli, on Kilauea in Hawaii and on the Katmai volcano in Alaska, which has been active since 1912 and is the largest crater at present known. As regards the founder of the journal, Benjamin Silliman was the son of a general prominent in the war against England. He was born in Trumbull, Connecticut, in 1779, and was a graduate of Yale College, New Haven, which later appointed him to the new chair of chemistry and geology after he had travelled and studied in Edinburgh, London, and on the Continent.

COKE HANDLING AT MANCHESTER CORPORATION GAS WORKS.

By George Frederick Zimmer, A.M. Inst. C.E.

The handling of incandescent coke is, as is well-known, the most difficult problem with which a handling engineer may be confronted, as the fumes from the coke, laden with sulphurous acid, as well as the corrosive action of the quenching water, have a tendency to destroy the mechanical parts of the conveyors with which they come in contact, for the "breeze" disintegrates the wearing surfaces, while the hot coke distorts and anneals them.

Although the advent of the hot coke conveyor in gas works was only a year later than that of the coal conveyor, i.e., about 1891, its infantile complaints were not altogether left behind when it reached the age at which one might expect maturity, though in this respect the coal conveyor left nothing to be desired. The degree of success recorded by the earliest coke conveyors was decidedly small—if, indeed, it could be spoken of as success. The coke was satisfactorily conveyed by them, but repairs and renewals were so costly that, in 1901, after the accumulated experience of ten years, at the meeting of gas engineers in Glasgow, the late Mr. W. R. Chester, of Nottingham Gas Works, practically proved that when mechanically-handling material of such destructive nature as incandescent coke, with the appliances then available, the point at which machine labour becomes more economical than hand labour was not easily reached, even when handling large quantities. No mechanical conveyor can be an economic success over hand labour, when the quantity to be handled annually is below a certain minimum figure, that is to say, a conveyor of an inexpensive type which takes little driving power, and the cost of upkeep of which is likewise small, would become more economical than hand labour for a comparatively small annual capacity, while a conveyor requiring large capital outlay, much driving power, and considerable cost for upkeep, could not be more economical than hand labour, except for very large annual capacities. At that time it was estimated, on the basis of Mr. Chester's figures, that the cost of handling hot coke mechanically from the retorts to the heap in the yard, was 6·47*d.* per ton, inclusive of repairs and renewals, as well as 3½ per cent. interest on capital outlay. With hand labour at the, then, state of the labour market (1901), a man removed 15 tons of coke per day from the stage floor, quenched and delivered it at the coke heap in the yard at a cost of 4*d.* per ton, to which must be added 1*d.* per ton for renewal and repair of the barrows, bringing the total to 5*d.*, thus showing a balance of 1½*d.* per ton in favour of the manual performance.

We have seen from the foregoing remarks that a considerable amount of destruction is inevitable when dealing with hot coke, common sense, therefore, suggests that the simplest, most inexpensive, and most easily repaired receptacle be used for the purpose, as wear and tear can then be centralised to a simple part and made good with a minimum of delay and expense. These conditions are fulfilled by an intermittent handling machine, such, for instance as the telpher, or the machine forming the subject of this paper, the skips of which can be repaired by any blacksmith, the expensive parts being well out of the way of injury. A continuous conveyor for hot coke, on the other hand, cannot be repaired as quickly nor at anything like so low a figure, it being exposed to injury in practically all parts, and for its whole length. There are, however, many instances where a continuous conveyor is more suitable owing to the lack of headroom necessary for a telpher, or for other causes.

Hitherto the adoption of mechanical devices for dealing with hot coke has been dependent upon the size of the works, their general lay-out, and the abundance, or otherwise, of manual labour. Different devices have received the support of different engineers, according to the local conditions obtaining at their works. Where mechanical handling devices have been installed the choice has fallen on either one of various forms of continuous conveyors, or on a telpher plant. Very few works nowadays would consider the question of taking out the hot coke in barrows.

Continuous hot-coke conveyors may be of either the drag-bar type, which pushes the coke along, or the continuous-plate type, which carries the coke, both work in a trough partly filled with water. Both types have their supporters, the former being, as a rule, the favourite. These conveyors are expensive in first cost, and the repairs and renewals are also big items, as is only too well-known, and as is consistent with the nature of the circumstances.

A telpher plant in a retort house, though generally an improvement on the continuous conveyor, has also its disadvantages, which are, however, more or less contingent to all intermittent systems. A charge from a retort has to be picked up, quenched, and taken away to the storage pile in the yard before the telpher can get back to take the charge from the next retort, but

COKE-HANDLING PLANT AT BRADFORD ROAD GAS WORKS, MANCHESTER.

CONSTRUCTED BY MESSRS. DRAKES, LIMITED, ENGINEERS, HALIFAX.

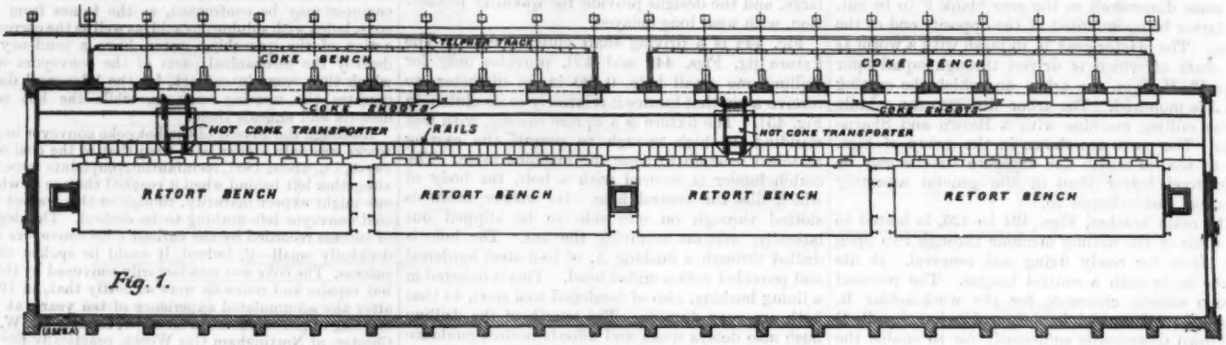
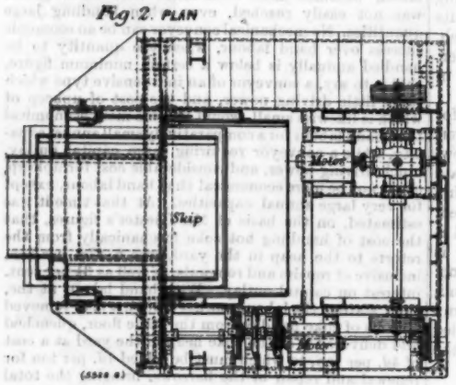


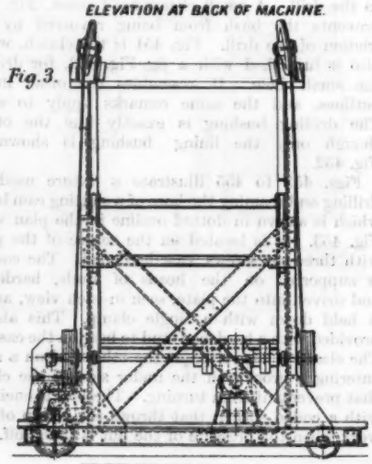
Fig. 1.

Fig. 2. PLAN



ELEVATION AT BACK OF MACHINE.

Fig. 3.



ELEVATION AT FRONT OF MACHINE.

Fig. 4.

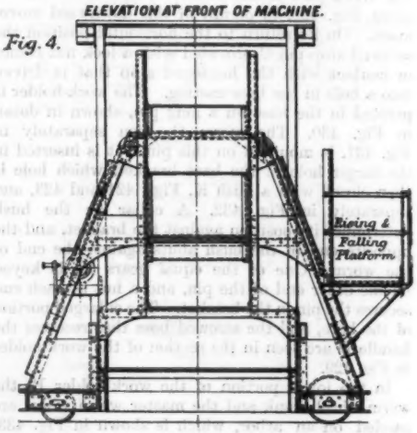
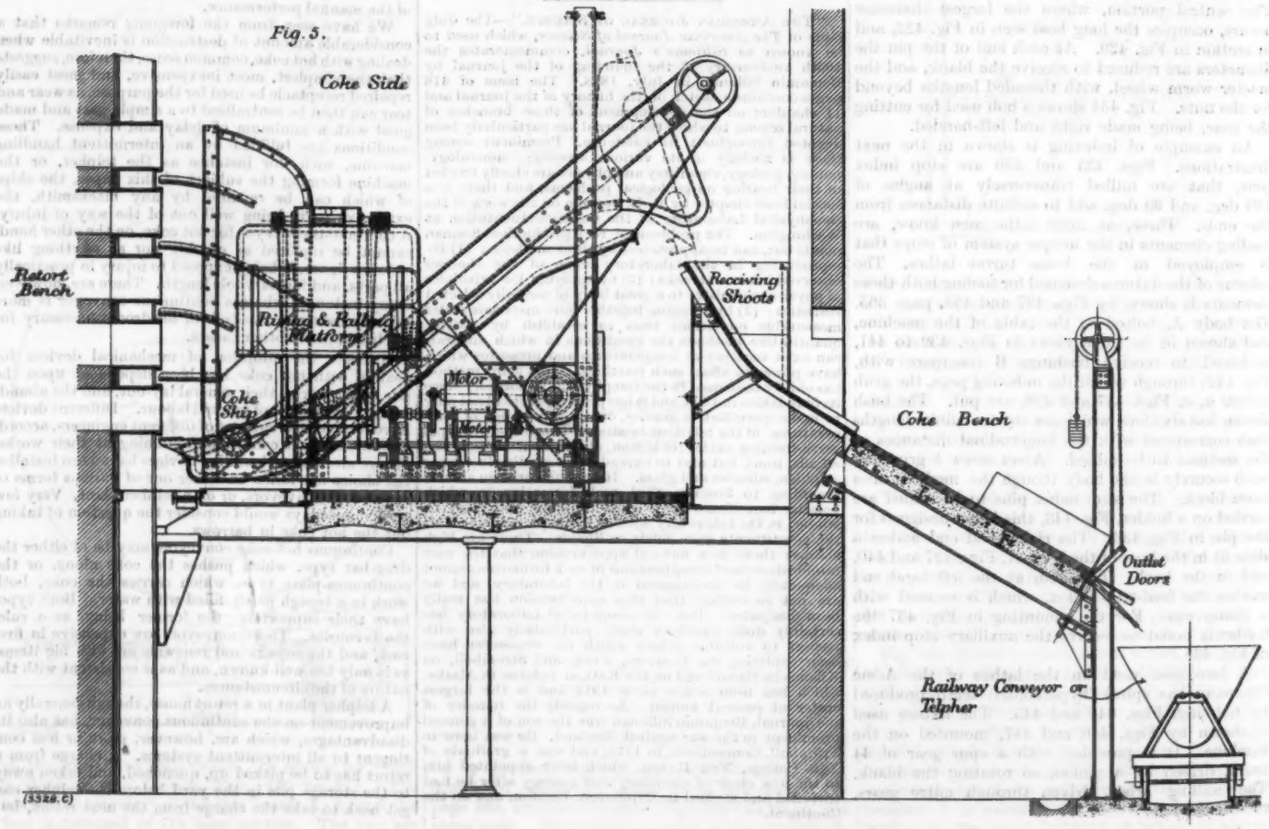


Fig. 5.



this can be minimised by employing more than one machine. What is of more importance is the fact that both the conveyor and telpher run parallel and in close proximity to the retort benches, so that the coke, in order to be removed has to pass in front of all the intervening beds between the points where it is received and delivered. As we have seen, in some of the conveyors the quenching of the coke is performed in the trough, and the steam thus produced renders attention to the mouthpieces of the retorts difficult, and fills the house with vapour, which is detrimental to the roof and other structural work, owing to the condensation on such cold surfaces and the consequent dripping of water and dirt on those beneath.

The new machine brought on the market by Drakes, Limited, of Halifax, as the "Ideal" system of hot-coke transport, appears to overcome all the difficulties above set forth, and at the same time embodies the advantages of any coke-handling device yet introduced, as will be seen from the following description :—

A ground plan of the Bradford-road Gas Works of the Manchester Corporation is given in Fig. 1; it shows the retort benches, the rail track with the coke discharging machine, and the numerous openings in the wall through which the coke is discharged on to the quenching bench or hearth "outside" the retort house.

Fig. 6.

The machine proper is shown in Figs. 2, 3, 4 and 5, the last-named view being a cross-section through the retort house and quenching bench, the latter being shown also in Fig. 6. Figs. 7 and 8, on page 376, are photographic views, showing the skip in two different positions, namely, its lowest and highest. The appliance is mounted on a bogie running on rails in front of the retort bench, and is similar to an inclined elevator with one large bucket, or in other words, is like a skip hoist, used for boiler-house refuse, which is similar to coke in its destructive nature. The coke is delivered by a steel-cased multiple shoot into the skip from the various tiers of retorts; this shoot is attached to the travelling carriage of the machine by a steel channel frame, and has ample bracing to ensure rigidity. The vanes of the shoot are arranged to project slightly beyond the cast-iron mouthpieces of the retorts, so that the whole of the coke passes into the skip without any spilling. The shoot is almost entirely enclosed, thus shielding the operator from the intense heat.

A retort of a higher tier does not mean a greater fall for the coke, as the skip is raised further up the incline to receive its load. In working, the skip is set at such a position at the bottom of the shoot that the coke is received with a minimum of fall, thus obviating the formation of breeze. This skip travels on four wheels on double tracks and the divergence of the lower one, on which the forward wheels travel, causes it, when it reaches the top, to slowly tilt, so that the coke is discharged gently into the fixed shoot in the retort house wall prepared to receive it, and down which the coke slides on to the quenching bench outside the retort house, where it is spread in an even layer and quenched with a minimum of trouble. Instances of insufficiently-quenched coke are altogether unknown.

The skip cradle is raised on its inclined path by means of two steel-wire ropes, one at each side, which are each tested to 6 tons, and which run round two large guide pulleys at the top. The track is constructed of steel channels and angles, and has attached to the underside a steel plate, guard, or shoot, which prevents any coke which may be accidentally spilled from the skip in tipping from falling on to the men when passing round the machine. The guide pulleys and hoisting drums are of ample size in order to reduce the wear and tear on the wire ropes, due to constant handling. The hoisting drums are of cast-iron, made in two sections, each having an inner barrel and an outer grooved sleeve, and so arranged that the sleeve may be adjusted to any desired position in order to keep an equal tension on both hoisting ropes, and also to take up any inequality in their lengths. The four runner wheels on the skip, and the guide pulleys for the ropes, are mounted on roller bearings in order to eliminate friction as much as possible.

There are two electro motors, one for travelling, and one for hoisting, both of which operations can be carried on simultaneously; a skip load need not, therefore necessarily be dumped on the nearest part of the hearth. These motors are of the totally enclosed dust-proof type.

The travelling carriage of the machine is a strong framework of steel channels, to which the hoisting and travelling motors are secured. The travelling wheels are of cast-steel, and have machine-cut spur rims bolted thereto, the power being transmitted from the travelling motor through a train of mild-steel machine-cut gear wheels.

An adjustable platform is provided for the attendant for the purpose of opening and closing the mouthpiece lids on the retorts of the upper tiers; this platform is counterbalanced and can be operated with ease by means of a handwheel, from the driver's platform. A steel-plate shield is fixed to the "lidman's" platform, to prevent his suffering any discomfort from the heat of the coke, there is also an automatic safety device which comes into operation should either of the steel-hoisting ropes break.

The coke skip in this installation is 7 ft. long and 5 ft. wide, and of a capacity to receive the contents of one retort (24 in. by 18 in. by 22 ft.). It is constructed of steel plates and angles riveted together, and is mounted on a separate cradle or carriage, being easily removable when necessary. It may be interesting to note that whereas, on the installation of the plant, the manager, Mr. Hill, was prepared to renew the skips every fortnight, if need be, so long as the system handled his coke expeditiously, yet the original skip fixed in December, 1916, has been continuously at work ever since without any need of repair. The skip cradle is constructed of steel channels, to which are fixed forged-steel trunnions for the runner wheels, which are of cast-steel and fitted with roller bearings as well as the guide pulleys, which revolve on steel pins fixed in the brackets at the top of the track frame. The hoisting gear consists of two drums or barrels, one on each side of the machine, keyed on to a common shaft, which is driven through worm gearing by a totally-enclosed reversible crane motor. In addition to the worm gearing, there is an automatic solenoid brake, and by stopping the motor, the skip may be instantly brought to rest at any desired point on the track, as, for instance, when it is desired to set the skip in position for receiving the coke from the upper tiers of retorts. At the upper and lower ends of the track there is, moreover, an automatic cut-out switch, which renders over-running of the skip impossible. In actual working the skip is automatically stopped on the hoisting motion, the attendants using the controller to stop the skip on the lowering motion only, when dealing with the upper tiers of retorts. Two controllers of the tramcar type are employed, one for the hoisting and one for the travelling motion, and it is possible for the operator to both travel and hoist at the same time. The electric current, which in this case is 400 volts D.C., is taken from overhead cables.

One very important feature of this system is the fact that by utilising a coke-quenching bench outside the house, instead of delivering directly into telpher skips, conveyors, &c., the operations inside the retort house are not dependent upon the removal of the coke to the storage plant, it can, in fact, be quenched and remain there as long as desired, provided it is taken away before the next round of retorts is due, and if there is not sufficient room for the second round to be discharged on the bench while the first round remains. Even should there be a glut of coke at any one point on the coke bench, delivery can be effected with this machine at any other point desired. It is, however, far better to clear the coke from the retorts as it is made, and there is plenty of time for doing this in between the rounds. It will be seen that where the ordinary coke is desired without screening, it can be delivered direct from the quenching bench into carts, thus avoiding handling in other directions. Fig. 6 shows a portion of the quenching bench and a small train of tipping trucks for the purpose of removing the coke.

The actual time taken in discharging a 24-in. by 18-in. retort, 22 ft. long, and depositing the coke on the quenching bench, is 35 seconds, and the skip is again in position to take the next retort in a further 10 seconds, the whole cycle of operations being performed in 45 seconds. With a complete installation of carbonising, on the system advocated by Drakes, Limited, the time expended, per retort, in a large retort house, is well under one minute. We thus see that the coke is transported in a bee-line from the retort, and at right angles to the setting, to the outside of the house, the distance travelled by each charge being reduced to a minimum, and under no circumstances does any hot coke or coke dust come in contact with any moving parts, these being all away from the heat zone. This provision ensures a long life for the working parts, and greatly facilitates lubrication.

Two operators are required per shift, one for driving the machine, and the other for attending to the mouthpiece lids, in a small works it would be quite possible for one operator to attend to both. With this system there is no coke spilled, and the retort house is always clean and tidy, and, as the photographic views, Figs. 7 and 8, show, the atmosphere is as clear as it possibly can be in a retort house. The machines are too new for us to be able to record any data concerning their lasting qualities. One advantage, however, common to both the continuous conveyor and the telpher, is lacking here, and that is the depositing of the quenched coke on the heap in the yard; for with the "Ideal" system an auxiliary device is necessary to remove the quenched coke from the hearth to the heap, the additional expense involved for this is, however, insignificant when weighed against the many advantages, furthermore, the quenched coke is so much easier to handle. We would suggest the use of a similar machine, also on rails in front of the hearth, by means of which the quenched coke could be stacked on a stock heap parallel with the retort house and of equal length.

By the courtesy of Mr. J. R. Hill, the manager of the Bradford Road Gas Works, of the Manchester Corporation, we are able to give an approximate idea of the economy effected by the use of this coke-handling system at the works under his control, although he has not yet been able to go fully into the cost of handling. The following figures will give some idea. He is carbonising 200 tons of coal per day, and estimates the saleable coke at 10 cwt. per ton of coal; this machine handles 100 tons per day. One man is employed per shift, at 10*s.* or 1*l.*, for the two shifts per day. The expense of getting the coke out of the retort house is, for manual labour, not including driving power, repairs, and capital expense, 2·4*d.* per ton. The consumption of current for the whole of the retort house is approximately, 160 units per day of 24 hours; Mr. Hill estimates that the coal handling and breaking plant

consumes 75 per cent. or 120 units of this; the Fiddes Aldridge stoking machine takes, approximately, 30 units, leaving about 10 units for the hot coke conveying, which is very low.

INDUSTRIAL NOTES.

The Glass Industry Interim Industrial Reconstruction Committee—formed under the ægis of the Ministry of Reconstruction, the Board of Trade and the Ministry of Labour, of an exact number of representatives of Employers' Associations and Employees' Unions in every section of the glass industry—learn that after the war, Germany will seek to restore her credit abroad by a concentration of effort upon the export of certain chosen manufactures. Chemicals are named as the first of these manufactures, then comes glass.

Before the war, the British glass manufacturer and his men had, owing to Germany's hold, little chance of profit or employment. There is now opening in the glass trade for investment of capital and for well-paid skilled labour.

The committee want glass manufacture in Great Britain to be carried out under conditions that will give security and return to capital; security and return to brains; and security and substantial wages and good conditions of employment to the workers. Progress has already been made to put the trade in a good position to meet the future. The Society of Glass Technology affords a common meeting ground for labour, capital, science and technics, and every branch of the industry is to be represented on the committee and the district councils under it.

But, according to the committee, this is not enough. Germany's rise has been attributed directly to the British policy of the "open door," and the glass industry fears that this policy may be carried to such an extent that the industry may become extinct. On this point, the committee add, "Employers and workers think alike. Reform of this condition and help during the reconstruction period is not a political question but a business proposition. The German Government will spare no pains or expense to secure return to their virtual monopoly in optical and chemical glass, and their commanding position in glass generally, because they perceive very truly how that return would lead to supremacy in other industries and manufactures. The British glass industry does not intend to allow this return if it can help it. But it asks from our rulers some support. It does not ask them to bolster up an inefficient industry so that this may make profits at the expense of the nation, but it does ask that the industry be given the chance of full development and that a 'key' industry be saved from the hands of Germany, determined to capture it at all costs because it is a 'key.'"

Sir Guy Calthrop, the Coal Controller, addressed a meeting on Friday, September 27, at the Board of Trade, Coal Mines Department, and stated that gas and electric light rations would commence from the meter readings to be taken for the period ending last Monday. Coal rationing would start from the day the householder signed his requisition form, provided it was sent in prior to the 31st inst., after which date the belated applications would receive less consideration. Sir Guy called attention to the fact that at the present time there was less difficulty in supplying anthracite than any other class of coal, and expressed the wish that the use of anthracite be extended as much as possible. He was very much afraid that owing to the recent railway strike in South Wales some weeks would elapse before the effect of the stoppage would cease to be felt; in any event there was no hope of making up the serious loss of output which had occurred.

Sir Albert Stanley, President of the Board of Trade, and Sir Guy Calthrop, addressed, on Sunday last, a meeting of about 6,000 coal miners at Hayes Heath, the centre of the Cannock Chase colliery district. Sir Albert urged the owners, managers and the whole of the officials in the mines to play their part. He asked that all dissension should be laid aside and that work be carried out in a spirit of unity to bring the war to an end. Sir Guy said that the average output in Cannock Chase was 97,000 tons per week; the best week recently was 102,000 tons. He wanted the men to make it between 115,000 tons and 120,000 tons. At the close of the meeting a resolution was passed, recognising the need for increased coal output in the present crisis, declaring that the shortage was largely due to the recent recruitments, urging the necessity for a return from the Army of a sufficient number of fit miners irrespective of their medical category if the desired increase was to be achieved and maintained, and pledging the meeting to do everything in its power to reduce avoidable absenteeism and maintain the highest possible output.

Mr. W. L. Hichens, chairman of the directors of Messrs. Cammell, Laird and Co., Limited, speaking at a dinner given in his honour on Saturday last, by the "Foremen's Fraternal" of the firm, said that the head of a business was not primarily concerned with the question of profits. He was there to try to keep a balance between the different elements in the business. He had to consider the shareholders, but he had also to consider two or three other things. He had to consider the stability of the business. He had to see that there was enough reserve made so that the business would not find itself at the bottom of the sea and everybody thrown out of employment in times of stress. His great anxiety was to see that it was built on a solid foundation for the sake of everybody concerned. He was anxious to have a contented staff of employees around him, because he knew perfectly well that unless he had the business was bound to fail. It was his duty to strike a balance between all, and if he did so properly he was criticised by all. The shareholders wanted higher dividends and the employees higher wages. That was only human nature. But the head of a firm had to strike the balance between the conflicting interests. In doing that one wanted a lot of help, and it was for that reason he welcomed the establishment of the Fraternal.

He hoped that his firm was, one of these days, going to stand for a big principle in industry. Business in future could rest successfully only on that. If it was going to stand only on the sordid basis of profit it could not exist in this country or anywhere else. It was extremely important that those responsible for industry, either on the one side or the other, should think out clearly and deliberately what they wanted. With this end in view he proposed at a later date to meet them in free and frank discussion of the subject. Personally, he believed that foremen and managers often had a thankless and difficult job in respect of some aspects of industry; but their positions, and the spirit they exercised in future administration, would count for much in helping forward new ideals and the new spirit in industry. When addressing a meeting of Socialists a little while ago he was met with the proposal that foremen should be elected by a vote of all the men in a shop. With such a suggestion he could not agree; and certainly he would not be an elected foreman at any price. Such an individual would deserve a lot of pity. Frankly, in his opinion, there was a great deal too much loose talk about the democratisation of industry. Inside the works somebody must say what was to be done, and the other man must do it if a business was to be successful; but outside the works all men must be equal, and act as one gentleman dealing with another.

Mr. Hughes, Prime Minister of Australia, speaking last week at a presentation from the National Federation of Trade Unions to Captain O'Grady, M.P., stated that when the war was over many months would elapse before the Australian troops now fighting in France and elsewhere could be got back home. He knew all about the trade union standpoint, and did not ask them to do anything that was not compatible with the spirit of unionism, but to do all they could, and in a spirit of brotherhood and admiration for what the Australian soldiers had done, to throw open to them the gates of opportunity, so that during, say, the twelve months they were awaiting their return home, they might enter the workshops of this country, and, instead of loafing about, occupy their time usefully to themselves, to the country, and to the Empire. It was not at all a question of money; the unions would make their own conditions on that point. Fully 75 per cent. of the Australian soldiers were either trade unionists or the sons of unionists. He did not ask trade unionists for preference, but simply that, consistently with unionism and the claims of their own soldiers, they would allow the Australian soldiers to work in their workshops for a short period after the war.

The general secretary, Mr. W. A. Appleton, replied that, as a federation, they would help the Australian soldiers all they could, and he promised to communicate in the matter with every union connected with the federation.

The question of reinstating the men from the army was also dealt with by Mr. G. H. Roberts, M.P., Minister of Labour, at a meeting in Sheffield, last Monday, of chairmen and vice-chairmen of 45 Local Advisory Committees in the Yorkshire and East Midlands Division. Mr. Roberts said he had recently been to the front in France and had told the men of the plans which were being entertained for demobilisation and of the formation of Local Advisory Committees for the purpose. When they returned they would be welcomed back by representative fellow-citizens, and demobilisation would be carried out speedily, smoothly and satisfactorily. Everything would be done to expedite the resettlement of the men in civil life. The Ministry had been charged to deal not only with the rank and file, but also with the officers, and committees were now engaged in thrashing out schemes of employment and education for these officers. The war had brought out many qualities in men of humble origin, and these men ought not to be expected to return to the comparatively humble positions they occupied before the war. What the Ministry wanted was to promise the men that as soon as they were released employment would be found for them at a rate of wages which would maintain them and their families in a state of decency and comfort.

We read in *Engineering and Mining Journal*, New York, that in a suit brought to recover damages for injuries to a plaintiff, who was injured from a fall of rock in the defendant's mine while operating a compressed-air drill, after having been assured by a shift boss that the place was safe, it was claimed by the defendant that the shift boss and plaintiff were fellow-servants within the rule of law still applicable in many jurisdictions, that an employer is not liable for injury to an employee, resulting from carelessness of a fellow servant, excepting where it is shown that by reason of known incompetence or habitual negligence of such fellow-servant the employer may be found to have been negligent in retaining him. But the United States Circuit Court of Appeals, Ninth Court, overruled this claim, holding that the shift boss must be regarded as the representative or *alter ego* of the employer, especially in view of an intention to make him the arbiter of the safety of working places, manifested by a rule adopted by defendant mining company, to the effect that each miner must assure himself of the safety of his working places, notifying the foreman or shift boss, if necessary, to remove the danger arising from any unsafe condition found. (Anderson *versus* Federal Mining and Smelting Company, 247 Federal Reporter, 472.)

Owing to the strong action taken by Government, the strikes of shipwrights on the Clyde and of railwaymen in South Wales, referred to on page 340 *ante*, have ended, and the men have returned to work.

The adjourned fourth ordinary general meeting of the Mond Nickel Company, Limited, was held in London last week, when Mr. Robert Mond, J.P., the chairman, said it had become fashionable in the last few years to designate certain industries as "key industries." Personally he had the greatest difficulty in finding a suitable definition of a "key industry," but in the accepted sense of the word the industry carried on by the company was one of those "key industries" which were of vital importance to this country. The use of nickel in its various forms, and of copper sulphate for the preservation of our food plants, were of the utmost value for the maintenance of our country, and he would like to lay stress on the advantages accruing from the possession of an important refinery of Canadian ores situated in this country. Not only did the company employ British labour, but by having to carry a large stock of raw and intermediate products to ensure uninterrupted work in their establishments here, they provided a large reserve of those essential materials which would safeguard this country against any temporary interruption of the regular supply from any cause whatsoever.

He thought it was necessary to utter a word of warning against the continued and increasing tendency on the part of Government authorities to interfere with the management of industrial concerns and to put restrictions upon a reasonable freedom of trade. Many businesses had, no doubt, sprung up during the war whose prosperity was entirely due to the extraordinary demands and conditions created by the war, but this could not be said of the Mond Company, the success of which had been assured before hostilities commenced. He felt it incumbent upon him, as chairman of the company, to draw attention to the great and growing danger to British trade of this continued Governmental restriction and interference. That there was a growing dislike of Government control of industry amongst all classes, employers and employed alike, was palpable to any ordinary observer of the trend of public opinion. It had been submitted to during the war because people considered it was necessary, and because they feared to do anything which might injure the national cause; but it would be quite a different matter if any attempt were made to continue control for a moment longer than was absolutely necessary. British trade had hitherto progressed and held its own against all comers without Government support or interference, and he was convinced it would do so in the future.

Price of Aluminium.—The Minister of Munitions announces that the control price of aluminium ingots of 98 per cent. to 99 per cent. purity will be reduced, as from January 1, 1919, from 225*l.* per ton to 200*l.* per ton, carriage paid to consumers' works. The price of re-melted aluminium scrap and swarf ingots will remain as at present.

ON THE COOLING OF STEEL IN INGOT AND OTHER FORMS.*

By J. E. Fletcher, Dudley.

(*Continued from page* 344.)

Effect of Variable Speed of Cooling.

Cast-iron, especially if low in total carbon, when cast into typical ingot form, yields very useful results in the study of mass influence on the rate of freezing and cooling.

Such iron ingots were cast into iron moulds of various thickness, and temperature curves of the heating up of the moulds at different points within the mould mass were taken. The results of trials in a relatively heavy mould are shown in Fig. 7. The mould was 13 in. outside diameter with a bore of 5½ in. and rested on a bed of sand, the bottom of the ingot being thus in contact with sand. The temperatures were taken at points ½ in., 2½ in. and 2½ in. from the outside of the mould.

It will be seen that the curves show a slow heating up of the mould during the first minute after casting. In other repetitions of the experiment with sand moulds as well as with metal moulds this lag is clearly indicated. It apparently coincides with the period of freezing of the ingot, the internal heat evolved at the moment of solidification being absorbed in intercrystalline reactions which appear to affect the rate of heat flow outwards to the mould. It is obviously associated with the phenomena observed by Professor Turner in his experiments on the volumetric changes in cast-iron during cooling from the molten state.

The three curves indicate different velocities of temperature rise throughout the mass of the mould, as might be expected. The curves do not reach a common equilibrium point, due to the cooling action of the air on the mould exterior. It is noticeable that it is only when the ingot and mould cool down together slowly that there is reached, after 1½ hours, an approximately common temperature.

The curves show a slackening of speed in heating after about 3 minutes, the flat portions *a b*, *c d*, and *e f* (Fig. 7) being very marked. The same slackening and flattening of the heating curves has been noted in the case of ingots cast in thinner moulds but at a higher temperature. This phenomenon appears to be related to the recalescence range in the cooling of the ingot.

The relationship between the heating up of the mould and the corresponding cooling down of the ingot can be expressed by the equation (1):

$$M_1 \times S_1 \times (T_1 - T_2) = M_2 \times S_2 \times (T_4 - T_3)$$

Heat lost by Ingot. Heat gained by Mould.

Where $M_1 . M_2$ = Weight of ingot and mould respectively.
$S_1 . S_2$ = Specific heat of ingot and mould respectively.
T_1 = Initial mean temperature of ingot.
T_3 = Initial mean temperature of mould.
T_2 = Final mean temperature of ingot.
T_4 = Final mean temperature of mould.

By assuming $S_1 = 0{\cdot}17$ and $S_2 = 0{\cdot}14$ (Harker's experiments on specific heat), and by assuming T_2 and T_4 equal, it is possible to arrive at the ratio:

$$R = \frac{T_1 - T_2}{T_4 - T_3}$$

It will be found that the rise in temperature of the mould up to the flattening of the curves at *a b*, *c d*, and *e f*, if multiplied by the ratio R, will indicate the temperatures in the ingot corresponding with the slackening phenomena. It corresponds with the recalescence range at about 700 deg. C., and would appear to suggest that the heat evolved during recalescence is absorbed internally, and that, further, the external heat flow is retarded during this period. This phenomenon is noticeable during the heating of steel, and is clearly shown in Mr. E. F. Law's recent paper on the "Effect of Mass on Heat Treatment." The inflow of heat during heating through the Ac1 range is retarded, such retardation being very marked in the central portion of the forging under treatment.

Fig. 15 shows the temperature gradients throughout the mass of the mould at periods of 1, 2, 3, 5, 7, 10 and 15 minutes after casting. The dotted portions of the curves are hypothetical, but are probably correct. The velocity of heat transfer through the mould contact envelope or skin must be much greater than that further within the mould mass. The temperature gradient slows down as the mould approaches its equilibrium temperature, the values being related to the temperature head, *i.e.*, the difference in the temperatures of the ingot zone next to the mould surface and that of the mould in contact with the ingot. Further experiments are needed to decide the precise values of the temperature gradients in terms of the temperature head and of the thickness of the ingot and of its mould. It is known that the temperature gradients in the zone of ingot immediately in contact with the mould are proportional to temperature head, probably to the *n*th power of the head, where the value of *n* is variable. It has not been found possible to define the gradient curve mathematically as yet. In any zone the temperature gradient is the fall of temperature per inch of thickness, the heat being assumed to flow at right angles to the zone. It is difficult in the presence of so many variables to define the curves, but it is possible to arrive at comparative results, which may have not only interesting but practical value. The author therefore hopes that an attempt clearly to indicate the progressive steps by which he has attacked the problem of the heating and cooling of metallic masses will be of service. He has endeavoured to eliminate as far as possible the higher mathematics involved, though necessarily obliged to base his conclusions on the reasoning of Fourier and later physicists. First, the mean rate of cooling is directly proportional to the area of the outer cooling surface and inversely to the cubic content enclosed by the enveloping cooling surface.

The rate of cooling is seen to be always inversely as the diameter, side of square, or face of polygon, and decreases as the ratio of length to diameter or side increases. In ingots of similar weight the comparative rate of cooling (mean) is shown in column (3) of Table I.

Table I.

$R = \frac{C}{M}$ Values of Ratio R.	Form of Ingot.	Cooling. Relative Time.
$\frac{6}{s}$	Cube	83·33
$\frac{6}{d}$	Sphere	—
$\frac{5}{s}$	Cube where upper face is not cooled	100·00
	Square ingot open, top not cooled	111·00
$4{\cdot}5 \div s$	2 diameters long ..	—
$4{\cdot}33 \div s$	3 diameters long ..	115·00
$4{\cdot}25 \div s$	4 diameters long ..	117·50
$5 \div d$	Cylinder length equal to diameter	100·00
$4{\cdot}5 \div d$	2 diameters long ..	111·00
$4{\cdot}25 \div d$	4 diameters long ..	117·50
$4{\cdot}125 \div d$	8 diameters long ..	120·00
	All open top.	
(1)	(2)	(3)

Relative cooling time in column (3) is for ingots of equal weight cast in moulds of same weight as ingots themselves. Enveloping cooling surface in square inches. Cubic contents of solid in cubic inches.

From records taken of the rise in temperature of sand and iron moulds, Fig. 9 has been prepared. The interesting point brought out is that when the weight of the mould exceeds twice that of the ingot the increase of mould-metal thickness does not further speed up the cooling action materially. The effect of increasing the mould thickness in chilling or cooling the ingot or casting is greatest when the ratio of mould thickness to that of the casting or radius of ingot is below 0·25 in metal moulds and below 1·0 in sand moulds. In the latter the rate of cooling diminishes progressively as the thickness of the sand mould exceeds twice that of the steel casting. When the mould thickness (sand) exceeds eight times that of the casting any further chilling action is negligible. The practical use of the above investigation is obvious. It can be proved therefrom that a cast-iron chill half the ingot weight cast therein cannot stand, the temperature of the inner surface reaching the melting-point of cast-iron.

Table II.

	Ratio: Weight of Mould. Weight of Ingot.	Ingot Diameter.	Thickness Mould.	Ratio: $\frac{F}{R}$	Common Temperature C.	Approximate Time. Cooling to Common Temperature.
		in.	in.			min.
Iron mould	1·0	10	2·25	1·17	830	31
	1·5	10	3·10	1·76	663	23
	2·0	10	3·90	2·35	557	19
	3·0	10	5·30	3·52	425	14
	4·0	10	6·50	4·69	356	11
	8·0	10	9·75	9·38	213	6
Sand mould	1·0	10	6·50	2·73	504	225
	1·5	10	8·35	4·09	383	160
	2·0	10	10·50	5·46	313	130
	3·0	10	10·60	8·18	235	92
	4·0	10	16·30	10·92	185	67
	8·0	10	24·75	21·84	124	37
	16·0	10	36·75	43·68	88	19

In ratio $\left(\frac{F}{R}\right)$ $\frac{F}{R}$ is fall in temperature (mean) of ingot.

Again, the foregoing estimations and deductions only refer to mean temperature gradients, hence it is further necessary to investigate more closely the change in the gradient which gradually occurs between the outer surface and the axis of the ingot mass.

Taking first the case of the cooling of a spherical mass within a mould. The gradients are computed by conceiving the sphere to be built up of concentric hollow spheres surrounding a centre sphere, each hollow and centre sphere being of equal mass.

The surface of the outer sphere is cooled by contact with the mould, and there is a fall in temperature throughout the mass of the outer hollow sphere. The succeeding inner sphere is cooled by contact with the outer sphere, and so on until the central nucleus is reached. The ratio of cooling surface to volume decreases in each of the hollow spheres as the centre is approached, the fall in temperature in each of the zones being directly proportional to the ratio C/M, where C is the cooling surface and M is the mass or weight of the concentric hollow sphere or spherical nucleus. The fall in temperature in each zone divided by the thickness of the zone is the temperature gradient, which is the index to the speed of cooling. By assuming zones infinitely thin the curve of temperature gradient can be mathematically determined. It is sufficient to state that the temperature gradient does form a continuously falling curve from the outer surface to the core of the sphere, as plotted in Fig. 10. A similar study of the progressive cooling of a mass within a hollow cube mould shows that the curve of temperature gradients from the centre of each face inwards is the same as that of the inscribed sphere. The corners and edges of such a cube cool more rapidly than the faces, and this can be shown by a consideration of the elementary Fig. 11 (*a*), where a cube is divided into 27 smaller cubes. The mean rate of cooling is proportional to:

$$\frac{6 \times 8^2}{8_3} = \frac{54}{27} = 2, \text{ where } 8 = 3.$$

The centre of each face has the cooling ratio of 1, the 8 corner cubes have the cooling ratio 3, and the 12 edge cubes the ratio 2, whilst the central "kernel" cube has R = O. The mean ratio of the 27 cubes is therefore:

8 corner cubes	R 3	24
12 edge cubes	R 2	24
6 face cubes	R 1	6
1 nucleus cube	R 0	0
27		54

Mean ratio $R = \frac{54}{27} = 2$.

Again, assume the elementary cube to be built up of a number of concentric hollow cubes surrounding a centre cube, each zone being of the same volume. The outer cooling surface of each hollow cube acts upon the mass within it, the fall of temperature being proportional to the ratio C/M, where C = outer cooling surface of the hollow sphere and M = mass of same, as in the case of the sphere already considered. The temperature fall in each hollow cube (normal to the faces) divided by the thickness of the wall is the temperature gradient and the index to the rate of cooling.

The successive temperature gradients from the outside to the centre of the cube form a curve which is readily determinate. It is the same curve as that of the sphere of diameter equal to the side of the cube, Fig. 10. Further, following the same method of determination, the curve of temperature gradients can be fixed for the succession of cubes running diagonally from the edges of the outer hollow cube to the "kernel" cube (see Fig. 11 (*a*)), each of which has the cooling ratio R = 2. This curve is found to be the continuation of the one first determined, viz., that running from the centre of the faces to the centre of the main cube. The continuation portion of the curve increases in steepness as it approaches the outer cooling edge. Again and similarly the curve of gradients can be found for the succession of cubes running diagonally from corner to corner of the main cube, each of which has the cooling ratio R = 3 (see Fig. 11 (*b*)). This curve thus found is the continuation of the curve passing from the nucleus to the edges, the gradient becoming steeper as the corner is approached.

Fig. 11 (*c*) shows the combination of the three curves, and is practically useful in illustrating the fact that the progressive freezing and cooling of a square ingot at its base is that of a hemisphere within a semi-cube, the corners and edges of which are cooling at a more rapid rate than the faces. This, of course, is roughly understood in practice, but it has not previously been shown that the rates of cooling follow readily definable and continuous curves.

The lines of most rapid freezing and cooling therefore follow the paths of steepest temperature gradients, and these are the bisecting planes of the mould sides and those bisecting the base angles and constituting the base cone or pyramid first referred to by the author in a paper on the "Influence of Gases in Iron and Steel," read before the Staffordshire Institute in 1907, and since referred to by Messrs. H. and W. Brearley in their paper on "Steel Ingots" in 1916. In Table I it has been shown that the relative rate of freezing of long ingots is slower than that of short ones, the influence of the base chilling being greater the shorter the ingot. Hence the cooling of the central and upper portions of a long ingot is much slower than at the base, especially in bottom-run ingots, where the steel becomes gradually cooler as it rises in the mould. The temperature head then decreases continuously, and simultaneously the temperature gradients slow down as the upper portions of the mould are approached.

From actual determinations of the temperature gradients in cast-iron blocks cast in iron moulds arrived at from temperature rise readings at time intervals, it has been possible to deduce certain valuable basis figures, useful in the plotting of the probable isotherms within cooling masses, such as ingots.

Thus the heat absorbed by the cooling surface of a 5·5-in. ingot mould 13 in. outside diameter directly following the casting of the iron ingot was as under:—

(1) Time of casting and 4 minutes after.
Temperature rise per minute, 33 deg. C.
(2) 4 minutes to 12 minutes after casting.
Temperature rise per minute, 17 deg. C.
(3) 12 minutes to 20 minutes after casting.
Temperature rise per minute, 3 deg. C.

The heat calories absorbed per square inch of mould cooling surface in contact with the ingot was in periods 1, 2, and 3, 3·50 calories, 1·75 calories, and 0·30 calory per minute respectively.

* Paper read before the Iron and Steel Institute, on Friday, September 13, 1918.

THE COOLING OF STEEL IN INGOT AND OTHER FORMS.

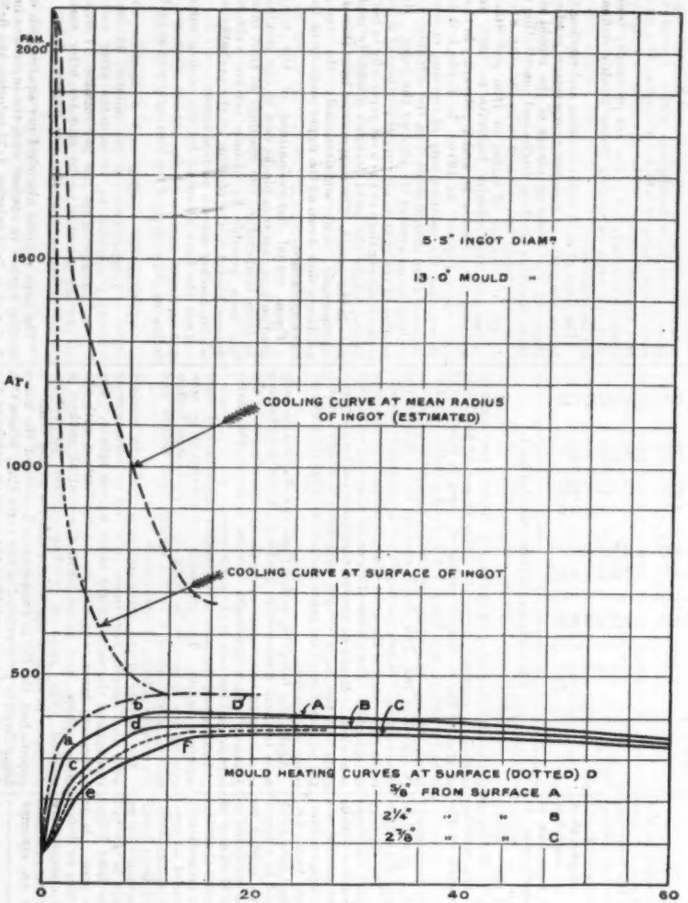
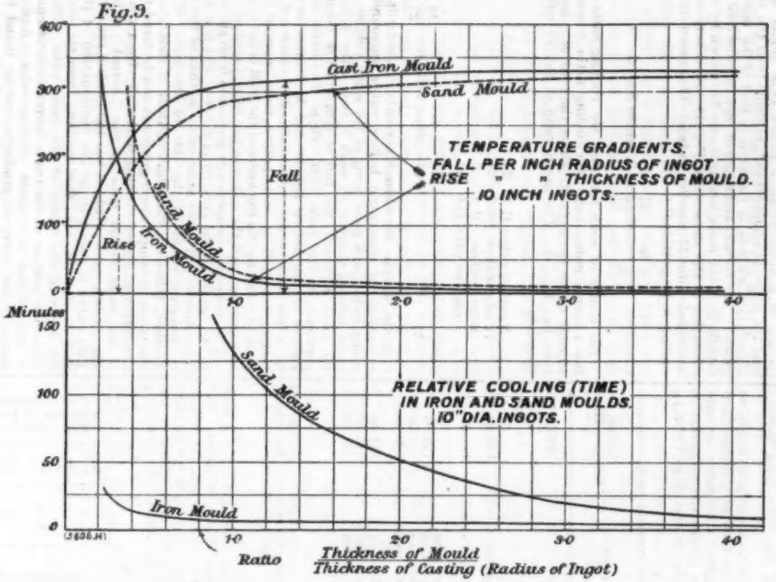
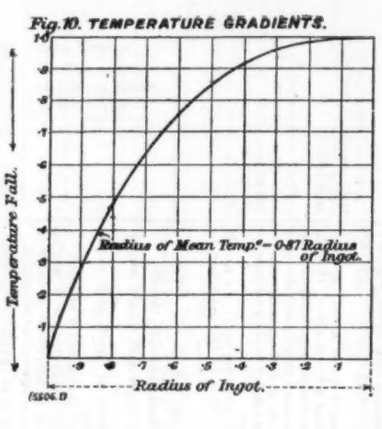
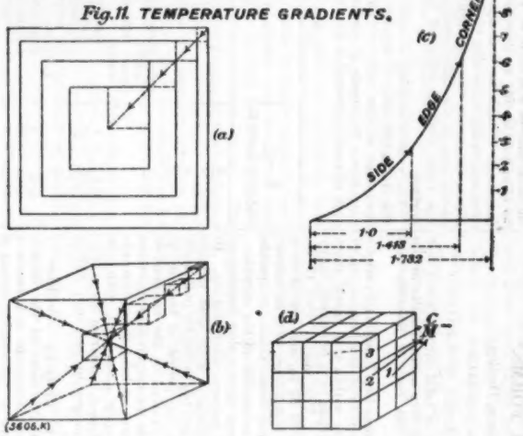


FIG. 7. COOLING OF CAST-IRON INGOT.







The temperature head in the period (1) was 1,180 deg. to 1,050 deg. C.
The temperature head in the period (2) was 1,050 deg. to 915 deg. C.
The temperature head in the period (3) was 915 deg. to 900 deg. C.

By equating the heat gained by the mould with that lost by the ingot it is easy to arrive at the fall in temperature (mean) of the ingot in each of the three periods following casting.

The temperature gradients obtained by measurement at fixed points in the mould and plotted from the heating curves enable the corresponding cooling gradients in the ingot mass to be predicted.

From such methods and from works observations made on the heating of ingot moulds of known weight, it has been possible to follow the case of a 12-in. square ingot 4 ft. long cast in a mould twice its weight, and to deduce from calculation and experiment the approximate isotherms within ingots cast in 1 minute and in 4 minutes respectively. The influence of casting wide or narrow end down, of top and bottom casting, and of closed top moulds has been examined, and the results of the calculations are illustrated in Fig. 12.

The effect of the chilling action of the mould during the teeming of the ingot has been calculated by plotting the values of the ratio R = C/M as the liquid rises inch by inch in the mould. From this it is possible to plot a similar curve indicating the mean fall in temperature at all levels from the bottom to the top of the ingot. In Fig. 12 two curves are shown, A giving the case of the ingot cast in 1 minute, B that cast in 4 minutes. The mean temperature fall in each case is plotted to show the state of things 1 minute after the ingot has been cast.

The isotherms corresponding to the temperature-fall curves are given in Fig. 12. The dotted line in Fig. 12 gives the modification in the temperature fall in the case of an ingot cast with narrow end down and with open top.

Suppose the casting temperature to be 1,500 deg. C. and the freezing temperature to be 1,480 deg. C. It is seen that the ingot cast in 1 minute is liquid in the upper half of its length, whereas that cast in 4 minutes has a solid envelope throughout its length of a thickness of about 3 in. at the centre of its length 1 minute after casting has been completed.

It is not contended that the diagrams are more than approximately correct, but the values of C/M taken in conjunction with observed values of the temperature gradients and of the heat absorbed per minute per square inch of mould contact surface during defined intervals after casting have been carefully checked from numerous

examples, and it is believed that the main features of the diagrams are correct. In the absence of correct values for the latent heat of fusion of steel the influence of such has had to be ignored. The result of such a correction would be to slow down the rate of cooling in heavy moulds and slowly teemed, with hot tops. The effect of rapid cooling of the base, corners and edges, together with the augmenting influence thereon of the liquid pressure head, is to round off the corners of the progressively freezing envelopes, this result being most marked in the case of small ingots cast in heavy chill moulds.

The base freezing is perhaps best followed in the study of the behaviour of an open sand plate whilst cooling from the liquid state. Such a square plate, for example, freezes first at the corners where, the occluded gases being ejected into the adjacent and central liquid portions, there is considerable shrinkage or contraction. The rate of freezing at the corners, edges and flat surfaces of a square plate is in the proportion of 3, 2 and 1 respectively, and is shown diagrammatically in Fig. 13. The pressure of the superincumbent liquid steel on the base of an ingot, or rather on the frozen plate first layer to form in the mould, has a bursting or tearing effect on steel is frozen in its rear and becomes attenuated and pear-shaped, the bulb end leading. It grows in volume as it reaches the axis by coalescing with other bubbles on the way. Such would strongly appear to suggest the reason for the usual shape of ingot "pipe."

Harmet compressed ingots, when compression has accidentally been stopped before complete freezing occurred, perfectly illustrate the above suggestion and prove that the so-called shrinkage cavity or "pipe" is gas filled, and in the compression process attains such high internal pressure as often violently to burst through and escape to the upper surface, Fig. 18.*

The influence of varying thicknesses of mould on the position of the "pipe," segregate zone, and blowhole contours is further shown in Fig. 4, page 343 *ante*, which is a useful commentary on much that has been contended. The diagram has been carefully prepared from the actual fractured ingots of nickel-chrome steel.

Temperature Gradients and Contraction.

The curve of temperature cooling gradients along a diameter of a cylindrical ingot shows that the fall of temperature per inch along the radius progressively from the outer skin to the axis is at first rapid and then diminishes gradually as the axis is reached. A 10-in. diameter ingot hypothetically built up of four rings of

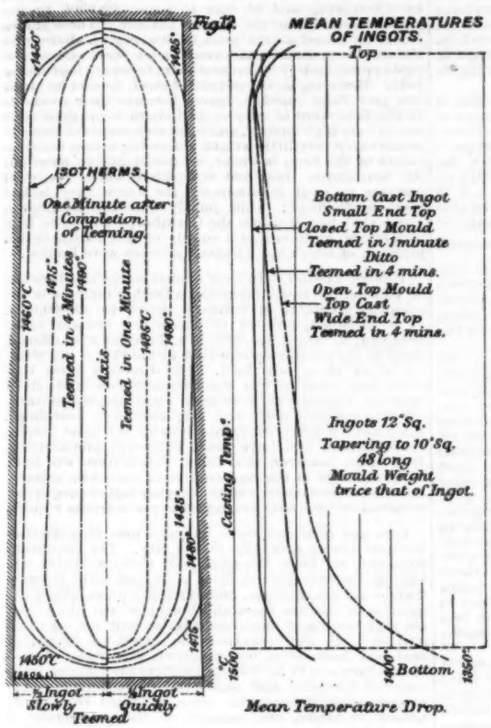


Fig. 13. RATES OF FREEZING AT CORNERS, EDGE, AND SURFACE OF SQUARE PLATE (OR INGOT BASE).

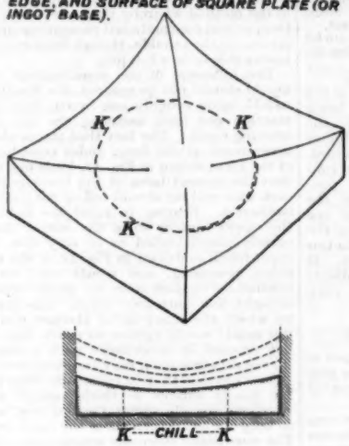


Fig. 16.

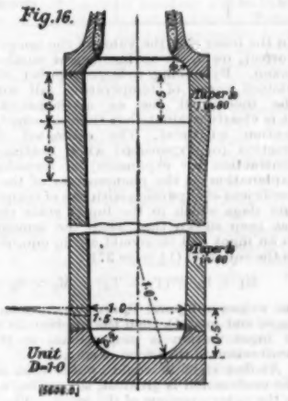
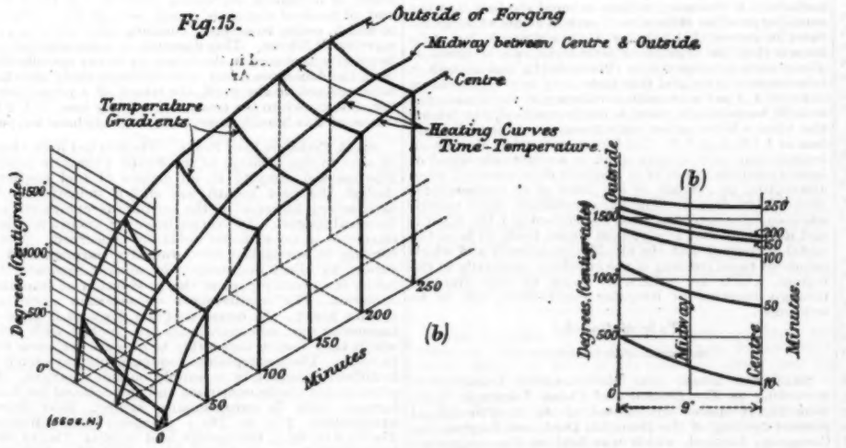


Fig. 15.



somewhat, the thickness of the envelopes would be slightly less per unit of cooling time than those shown. It is certain that the results obtained are comparative. With larger ingots the rate of cooling can be foreseen, it being recognised that this is inversely as the diameter and the mean thickness of the frozen envelope per unit of time will be proportional to the rate of teeming in the case of ingots whose moulds are of weight bearing a constant ratio to that of the ingot. The influence of slow teeming in moulds wide end uppermost is also indicated in Fig. 12. Here the envelope thickens rapidly in the lower portion and is thus strong to resist the internal liquid bursting pressure which in rapidly-teemed ingots in top cast moulds with wide end bottom is sufficient to burst the skin and to cause the surface defects pointed out by Mr. Kilby in his recent paper on ingot defects. Time teeming and the efficacy of slow pouring in comparatively heavy moulds has long been practised abroad and in some works here, but the recognised need for it is only now being generally understood.

The isotherms shown in Fig. 12 and the remarks made on edge, base and corner freezing lead to the conclusion that Messrs. Brearley's concentric freezing diagrams are not quite correct, the true form of the freezing envelopes being more approximately that of M. Harmet, especially in the case of smaller ingots cast the skin, cracks following the line of weakness *k k* in Fig. 13, where the thickness of the frozen skin is insufficient to resist the liquid pressure. This trouble is often seen in the base surfaces of ingots teemed too rapidly, and where bottom pouring keeps the centre of the base more or less fluid, or at least but thinly frozen round the runner brick area until the entire ingot is cast.

From the foregoing considerations it is evident that the rate of freezing in each of the concentric zones of an ingot as represented in the isotherm diagram, Fig. 12, is proportional to the temperature gradient crossing that zone, which gradient is again the measure of the volumetric contraction therein. As the occluded gas content in each concentric zone is relatively greater as the ingot axis is approached, the gas escaping to the "pipe" region accounts for the greater shrinkage in the central or axial zone. Indeed, if the gases liberated from hypothetical horizontal layers of progressively freezing metal be assumed to rise from the axial centre into the next higher layer, and so on until the ingot is completely frozen, the final volume of the pipe can be roughly estimated as a sphere, which becomes finally deformed into the usual inverted cone form.

This phenomenon is often illustrated in the gas bubbles which become entrapped between the outer envelope and the axis of unsound ingots. The initially spherical bubble as it travels inwards into the more mobile molten equal area had a temperature fall in each ring as under:—

Outer ring	...	810 deg. C., or 27·7 deg. per inch of mean circumference of the ring.
Second ring	...	625 deg. C., or 25·2 deg. per inch of mean circumference of the ring.
Third ring	...	389 deg. C., or 20 deg. per inch of mean circumference of the ring.
Inner ring	...	118 deg. C., or 10·8 deg. per inch of mean circumference of the ring.

This plainly indicates that the coefficient of contraction at the outside of the ingot is nearly twice that at a point midway between the axis and the circumference, that is, assuming the deformation per degree of temperature fall to be constant. But it is known that the coefficient of expansion or contraction rises with the temperature, just as might be conceived to be the case were the expansion or contraction due to the volumetric expansion or shrinkage of occluded gas. The estimated shrinkage on this supposition, viz., that shrinkage or contraction

* This figure will be given in a later issue.

is proportional to the occluded gas shrinkage (the estimated composition of steel at 1,500 deg. C. being 94·2 per cent. metal plus 5·8 per cent. of occluded gases by weight) is approximately proportional in each ring to the fall in temperature therein, per inch of mean circumference. Table III indicates that the contraction rate is proportional, very closely, to the shrinkage of the cooling occluded gases.

Table III.

Fall in Temperature in Rings.				
Outer.	Intermediate.		Inner.	—
1.	2.	3.	4.	
(a) 810°	625°	389°	118°	Fall in temperature in each ring.
(b) 27·7°	25·2°	20·0°	10·8°	Do. per inch of mean circumference of each ring.
(c) 3·8	3·4	3·0	2·5	Estimated volumetric contraction in each ring due to occluded gas shrinkage in percentages of initial bulk of molten ingot.
(d) 27·7	25·3	21·6	18·4	Values in line (c) × 7·3 for comparison with line (b).

In the inner ring the value of the temperature fall is not correct, owing to an insufficient number of rings being taken. By taking a large number of thin rings the plotted curve of temperature fall will closely follow the theoretical one as mathematically determined. It is clearly evident that there is something in the contention advanced. The estimated differential contraction (or expansion) when heating, based on the contraction (or expansion) of occluded gases, is one explanation of the phenomenon of the increase of the coefficient of expansion with rise of temperature in metals and slags which in the liquid state occlude gases. It has been shown that when the temperature gradients in an ingot and its mould are in equilibrium, *i.e.*, when in the equation (1), page 371 :

$$M_1 \times S_1 \times (T_1 - T_2) = M_2 \times S_2 \times (T_4 - T_3)$$

the values of T_3 and T_4 are equal (mean temperatures of ingot and mould), then the gradient in any zone or ring of ingot section is proportional to the coefficient of contraction in that zone or ring.

At first sight it would appear that in the outer ring the contraction is greatest, suggesting abnormal tension in the outer envelope of the ingot. The shrinkage of the occluded gases in the metal, however, may relieve the tensional strains in the outer layers of metal.

During the earliest moments of the cooling action within the mould when the temperature head is greatest, the temperature gradient is much steeper than at the moment of equilibrium when the mean temperature of the ingot and mould are alike. Hence it is reasonable to infer that there must be abnormal contraction during the brief period following the complete solidification of the ingot.

In this connection Fig. 15 (*a*) illustrates the different temperature gradients at various times after casting in the case of the cast-iron ingot, and Fig. 15 (*b*) those taken from Mr. E. F. Law's heating curves (experiments on the heating of 18-in. steel cubes). It has already been shown that the corners and edges of polygonal ingots have steeper temperature gradients than have the sides or faces.

There must therefore be considerable tensional strains set up at these corners and edges, an explanation of the rupture during the rapid heating of cold ingots, particularly if of high-carbon steel, in hot furnaces, whereby not infrequently the corners of ingots burst and fall off, fracturing along a path, conchoidal in form, which follows the outer curves of freezing at the ingot corners shown in Fig. 12.

The steep temperature gradients occurring in metal and other masses during drastic heating and cooling affect a wide area of practice. For example, the kilning of sharp-edged firebricks produces weakening effects at the edges and corners, rendering them brittle and liable to spall and fracture. In arch bricks this is a more serious matter than would at first sight appear, for the general rough character of the furnace builder's work throws severe strains on the flame contact face of the brick, in consequence of which the corners and edges very early become fractured, the fractured surfaces laying open the capillaries and hence leading to rapid wear through ferrous oxide penetration.

The author has proposed the rounding of the edges and corners of such arch bricks at the inner surfaces, with a view to securing a better moulded and burnt surface and to obviate the common spalling trouble. The arch thrust is thrown farther back behind the flame contact surfaces, and considerable saving is effected in the breakages common to handling and during the expansion thrust. A patent embodying these considerations has been applied for. The old Swedish method of casting ingots with the small end down and with the base end well rounded is obviously correct in principle, and is a practical and truly scientific mode of overcoming the tensile strains inseparable from square-based, sharp-cornered ingots.

Reference to the temperature gradient curves in Fig. 15 emphasises the fact that the freezing of the first thin envelope is rapid, though the thickening of the envelope proceeds slowly afterwards. It may safely be assumed that the liquid pressure in the upper part of a hot-topped ingot cast with wide end up is sufficient to keep the upper portion of the envelope (thin because of the slow rate of cooling there) in contact with the mould. The lower and thicker part of the envelope is attempting to contract in the direction of the feeding head whilst the upper portion is held fast in the mould, with the inevitable result of surface tearing. An illustration of this trouble has come before the author's notice within the past few weeks where such ingots have cracks horizontally running round the upper ends about a foot from the top, the hot cracks averaging 0·3 in. to 0·4 in. deep. The author has made an attempt to determine the proper taper of such ingots, bearing in mind the phenomena described.

In an ingot, say 24 in. square at top and 6 ft. long in the chilled part, the contraction up to the moment of stripping may be taken at 0·15 in. per foot linear. Suppose the solidification of the ingot upper portion is at the rate of one-tenth that of the lower, then the contraction at top will be 0·015 in. per foot, or 0·015 in. per side. The lengthwise contraction will be $6 \times 0{\cdot}15 = 0{\cdot}9$ in. The top of the ingot should therefore be able to fall in the mould 0·9 in. during a top shrinkage of 0·015 in. per side. The ratio $\frac{0{\cdot}015}{0{\cdot}90}$ is the maximum taper allowable, or 1 in. in 5 ft., per side. This can only be taken as a rough estimate, but is given as an indication of the method whereby the correct taper can be adduced from actual contractional measurements on ingots whilst setting in the moulds, though from experience the author knows this to be a hot job.

The influence of the simultaneous expansion of the mould should not be ignored, the linear expansion of the mould being roughly one-fourth that of the ingot contraction per foot, assisting the downslip of the contracting ingot. The fact that the isotherms in a cooling taper ingot of the form under consideration are curves of the form shown in Fig. 12, leads one to the conclusion that the correct form of the lower portion of the ingot cast wide end up should follow the contours of the outer isotherms. Bearing in mind the liability to top grip, the upper foot or so of the mould should be approximately parallel-sided or of very slow taper. Such an ingot form, as drawn in Fig. 16, is the result of the foregoing reasoning, and would tend to maintain more continuous contact with the mould than does the usual straight line contoured ingot. The intermittent jumps by which the ingot under Harmet compression rises in the mould would appear to prove that contraction does not proceed in accordance with a straight line curve, if such an expression may be permitted.

It is obvious that to ensure the best results the top of the mould should be thick enough to yield a thick envelope directly under the hot top, whose function is to keep the axial portions of the ingot top hot and liquid. The conditions there are antagonistic, but the practical results to be aimed at are clear.

In considering the problem of perfect ingot skin surfaces it is necessary to bear in mind the fact that the actual crystalline structure of carbon steels at temperatures in excess of 1,150 deg. C. is unknown, but it is known that the crystalline boundaries can be fused at about such a temperature (Standsfield), and though it is heterodox to suggest that there may be a formation of eutectic 4·3 per cent. carbon colonies at the boundaries at such temperature, there is much practically to favour the view. What other constituent would be likely to fuse at 1,150 deg. C.? The fact remains that above such temperature steel is very weak in an intercohesional or intercrystalline sense, as is specially demonstrated when attempting to extrude or die draw it at temperatures above 1,100 deg. C. The same weakness must prevail when an ingot is cooling from the molten to 1,100 deg. C., and it is clear that any process which tends to keep the metal in contact with the mould continuously and which promotes rapid freezing of the envelope, especially in the regions which are otherwise liable to skin fracture through bursting or irregular contraction, are to be welcomed.

(To be continued.)

Shanghai Dock and Engineering Company.—According to *The London and China Telegraph*, there were 20,216 shares represented at the twelfth annual general meeting of the Shanghai Dock and Engineering Company, Limited, which was held at the company's offices, Broadway. Mr. John Prentice presided. In the course of his speech he said: We are still suffering from difficulties and delay in procuring and getting delivery of materials, and, therefore, the completion of work has been and is still being very much retarded. During the year we delivered three steamers of a deadweight capacity of about 6,500 tons, and other of about 3,100 tons will be delivered shortly. We have also carried out a large amount of repair and renewal work. We consider the result of the year's working very satisfactory, and this is entirely due to the increased amount of work done, and we had the capacity for doing much more, had materials been procurable. The amount transferred from general working account shows an increase of nearly 66 per cent. over that of last year, which showed an increase of nearly 45 per cent. over the previous one. The net profit for the year, including the amount brought forward from last year, after paying all charges and allowing for all known liabilities, amounts to 1,154,142·72 taels, which we recommend should be dealt with as follows:—Pay a dividend of 14 taels per share, 772,800 taels; place to special reserve fund, 240,000 taels; place to depreciation fund, 70,000 taels; carry forward to new account, 70,742 taels. The report and the recommendations were adopted. The sum of 1,000*l.* was donated to the Sailors' War Orphans' Fund. Messrs. R. S. F. McBain and John Johnstone were re-elected directors of the company.

NOTES FROM SOUTH YORKSHIRE.

Sheffield, Wednesday.

John Brown and Co.—At the annual meeting of John Brown and Co., Lord Aberconway announced that in order to secure additional share capital the directors proposed to increase the company's capital by 1,000,000*l.*, and of that to issue 500,000*l.* to the shareholders during the coming autumn. These shares would be issued at the price of 30*s.* per 1*l.* share, and the directors would endeavour to let them out at the rate approximately of one new share for every four shares held. Referring to the output of steel, he said he could not give them tonnage figures because their products in Sheffield were of very special character; their steel was of very high quality, and mere statements of tonnage would carry very little weight. Two important developments of the firm, however, he would like to mention. At Scunthorpe they had completed works for steel castings to meet requirements for which they lacked room in Sheffield; while jointly with the Darlington Forge they had acquired the Carnthorpe Hematite Iron concern, so as to ensure a supply of this indispensable product, of which the available sources were limited.

Vickers, Limited.—In their annual report the directors of Vickers, Limited, announced a further increase in the company's capital in ordinary shares to 12,000,000*l.* It is proposed, subject to Treasury's consent being obtained, to issue 1,850,000*l.* new shares at 30*s.*, offering these to the present shareholders at the rate of one share for every three now held. The directors state that after four years of war the company now finds itself with an enormously increased plant largely suitable for war material only, and very extensive workshops. They have a peace programme under the most careful consideration, and have made extensive preparations. It is clear, however, that much expenditure will have to be incurred in the replacement of machines suitable for war purposes only, and in carrying higher proportion of stocks and working progress that peace trades require.

Iron and Steel.—A more buoyant tone characterises business circles generally in the city. The important successes on both Western and Eastern fronts are turning the attention of firms more and more towards their peace programmes, and extensive preparations are being made for the disestablishment of war plant, and the replacement of machines suitable only for munition purposes. In the meantime the enormous output of acid and basic steel for munitions continues. Open-hearth furnaces in increasing numbers are pouring forth material for shell and guns, while apart from these requirements, innumerable firms, recruited from every branch of trade, are engaged on the production of material for the aircraft and tanks which are making such a notable impression in France and Flanders. There is a rapidly increasing pressure for twist drills and all kinds of engineers' small tools, in the production of which, owing to severe "combing-out," there is great scarcity of labour. This demand, it is anticipated, will be greatly increased in the future by heavy specifications from the American Army, and although many girls have been trained to the work, the return of a proportion of the skilled men to the trade is absolutely essential, if the future of this branch is not to be seriously handicapped.

South Yorkshire Coal Trade.—There is but little change of note in the position of the South Yorkshire market. The marked scarcity of all classes of fuel continues, though the past month has shown indications of a satisfactory increase in the output as compared with July and August. Deliveries, however, are of a restricted character so far as home needs are concerned. A large tonnage is earmarked for Admiralty purposes and for export to allied countries; in several instances this forms the greater part of the production at important collieries. The requirements of munition works also remain heavy. In house coal the demand is an ever-increasing one, and merchants are blocked with orders which they find it impossible to execute for some time to come. The metropolitan requirements have rendered it difficult adequately to supply outside districts. The pressure for slacks continues and the demand for blast-furnace coke is exceptionally strong. Best branch handpicked, 27*s.* to 28*s.*; Barnsley best Silkstone, 27*s.* to 27*s.* 6*d.*; Derbyshire best brights, 25*s.* to 26*s.*; Derbyshire house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; best large nuts, 22*s.* 6*d.* to 23*s.* 6*d.*; small nuts, 21*s.* 6*d.* to 22*s.* 6*d.*; Yorkshire hards, 22*s.* 6*d.* to 23*s.* 6*d.*; Derbyshire hards, 21*s.* 9*d.* to 22*s.* 9*d.*; best slacks, 18*s.* to 19*s.* 6*d.*; seconds, 16*s.* to 18*s.*; smalls, 13*s.* to 14*s.*

Personal.—The B. and S. Company, Bristol, the original and sole makers of the "Kleensurface" high-speed steel protective hardening compound, have decided to withdraw the sole selling agency for the distribution of this compound, and to establish district agencies directly under their own control. In the meantime all inquiries should be addressed to the B. and S. Company, Engineers, Toolmakers, Precision Works, Colston-street, Bristol.

Naval Petty Officers.—A new Admiralty Order affecting the petty officers of the seaman, signal, telegraphist, sailmaker and stoker branches, provides that all time over eight years as petty officer, subsequent to June 30, 1918, shall count as chief petty officer time for pension, provided the men are recommended for advancement to that rating, and that it shall count also for increase of pay on their becoming chief petty officers. This arrangement is subject to reconsideration after the war.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—The fact that the Ministry of Munitions had sanctioned the observance of the autumn holiday on Monday by the industrial workers in the Glasgow area was signalised by a noticeable speeding-up of output at the latter end of the week, consequently the outlook is brighter than it was eight days ago. While the bulk of the steel at present being produced is that required for shipyard work, steel in large quantities for the many other Government jobs now on hand is greatly requisitioned. High tensile steel for shell bars is a steady demand, although, meantime, ship plates, both for new and repair work, top the list. Some export is now being sanctioned, but mainly, of course, to allied countries for war purposes, directly or indirectly. Where not fixed, prices are steady and likely to rise even higher than some of the "record" rates recently touched. All over the activity is undiminished.

Scotch Pig-Iron Trade.—The insufficiency of the available supply of pig-iron to meet the wants of consumers is giving rise to some considerable anxiety, and this despite the smelters' present extensive output. So greatly, indeed, are steelmakers clamouring for deliveries of hematite that in many cases this is having to be artificially cooled at the producing works in order to get it out of hands as speedily as possible. Then, after the local demands are met, there is practically nothing to spare for overseas consumers, no matter what their necessity, unless Government can be persuaded to release a few tons for one or other of the Allies with some specially urgent work on hand. In pre-war times the export of pig-iron of all grades was such a particularly heavy item, and such a money-making matter, that the present condition seems all the more abnormal. Prices, while steady and firm, may rise—there is not much chance of a fall for some time to come.

Shipyard Extension in Greenock.—The shipyard extension at present being promoted by Messrs. Caird and Co. (Harland and Wolff), Greenock, looks like being a proceeding of such considerable magnitude that a sub-committee of Greenock Corporation has made sundry suggestions regarding the building of suitable accommodation for the workers likely to be employed in the new premises in the near future, and in addition has prepared tentative plans for the widening of certain streets, for the building of others, and also for the extending of the existing tramway system to meet the expected requirements.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—There has been a marked improvement in the general situation of the South Wales coal markets this week. To a very great extent the dislocation occasioned by the recent railway strike has been overcome, though the effects of it are still being felt, and the loss in outputs consequent upon enforced stoppages of many collieries cannot really be made up. The export trade is brisk, but supplies are being absorbed on official and Allied accounts. Very little coal, therefore, is released for private trading, and owing to pressure of shipment on official account in requisitioned tonnage, several collieries are finding it impossible to meet the requirements of merchants. Small coals are taken up more extensively and the glut is not so great as has recently been the case. The inland demand is strong and deliveries here are heavily in arrears, particularly for household purposes. There is an abundant supply of pitwood, and it is suggested that the cutting of timber in home woods is now being overdone.

Newport.—There is an active export demand for Monmouthshire coals. Eastern or Western Valleys are the relatively easier qualities. Smalls are in good limited demand, but the lower grades are still weak.

Colliery Examiners' Wages.—After protracted negotiations an agreement has now been entered into between the colliery owners and the South Wales Colliery Examiners' Association. The new agreement, which was signed yesterday by both parties, sets forth the rates of wages and general conditions of employment, and it is to be retrospective to September 2. The minimum wages are fixed at 4*l.* 8*s.* per week plus war wage for six days, making a total of 5*l.* 8*s.* with 1*l.* 1*s.* extra for Sunday work. It is further stipulated that where the examiners are at present receiving higher rates of wages than those specified these should continue to be paid.

Regulating Coal Supplies.—It will be remembered that some time ago an appeal was made to the Coal Controller to exempt the South Wales coalfield from the strict operation of the Fuel and Light Order. Sir Guy Calthrop has now, in effect, conceded the application and has approved of the scheme which has been in operation in that area for the past 2½ years, and yesterday Mr. Finlay A. Gibson, the secretary of the District Coal and Coke Supplies Committee for South Wales and Monmouthshire, issued a circular giving details of the scheme which takes the force of an Order. The chief feature of the new Order is a reduction in the quantities to be supplied by collieries and merchants for inland consumption as compared with last year. It is laid down, *inter alia*, that all colliery companies in the South Wales and Monmouthshire district must supply the same merchants with the quantity of house coal in October, 1918, as they supplied in October, 1917, less 30 per cent.; in November, 1918, as in November, 1917, less 30 per cent.; and in December, 1918, as in December, 1917, less 30 per cent. Every coal merchant must supply for retail purposes, *i.e.*, to basketmen and coal hawkers, the same quantity in October, 1918, as was supplied in October, 1917, less 15 per cent.; in November, 1918, as in November, 1917, less 15 per cent.; and in December, 1918, as in December, 1917, less 12½ per cent. Merchants must, as far as possible, supply in October, 1918, the same householders as they supplied in October, 1917; in November, 1918, the same as in November, 1917; and in December, 1918, the same as in December, 1917. There are, further regulations making the important provision that if the coal produced at the collieries is more than is required for shipment, then the amount supplied by the collieries, merchants and retailers may be increased, and this gives that elasticity to the scheme which the South Wales coalowners desired.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—There is little new of moment ascertainable concerning Cleveland pig-iron. As was anticipated cancellation of unfulfilled contracts for foundry iron under the September allocations were unusually heavy, and with supply of foundry iron still short little improvement during the present month can be looked for. October allocations are being issued fairly freely, but makers show no disposition to commit themselves heavily. Some producers have stocks of No. 3, but they are unable to obtain labour to lift it, and the truck shortage continues another obstacle to distribution. Lack of foundry iron, however, is chiefly due to the unsatisfactory working of furnaces, and the consequent large proportion of output of inferior iron in place of better kinds. Thus forge pig-iron is very plentiful, and wherever this quality can be used no difficulty is experienced in arranging supplies. The tonnage available for shipment of Cleveland pig-iron to the Allies is satisfactory. For home consumption, No. 3 Cleveland pig-iron, No. 4 foundry, and No. 4 forge all stand at 95*s.*, and No. 1 is 99*s.*; and for export to France and Italy, No. 3 and the lower qualities are 122*s.* 9*d.* and No. 1 is 127*s.* 9*d.*

Manufactured Iron and Steel.—In the finished iron and steel trades pressure for delivery is unceasing. Heavy claims for shipbuilding material are for the time being delaying deliveries of some other orders. Principal market quotations stand:—Common iron bars, 14*l.* 15*s.*; best bars, 15*l.* 15*s.*; best best bars, 16*l.* 15*s.*; best best best bars, 17*l.* 15*s.*; iron ship plates, 18*l.* 10*s.*; iron ship angles, 13*l.* 17*s.* 6*d.*; iron ship rivets, 21*l.*; steel ship plates, 11*l.* 10*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel boiler plates, 12*l.* 10*s.*; steel strip, 17*l.* 10*s.*; steel hoops, 18*l.*; and heavy steel rails, 10*l.* 17*s.* 6*d.*—all f.o.b. at makers' works. Though export prices are not fixed, they may be given as approximately 40*s.* above home quotations.

Shipments of Iron and Steel.—The total clearances last month were returned at 36,317 tons, composed of 29,579 tons of pig-iron, 1,160 tons of manufactured iron, and 5,578 tons of steel, compared with the August total of 65,484 tons, composed of 48,593 tons of pig-iron, 589 tons of manufactured iron, and 16,302 tons of steel. Clearances of pig-iron to foreign ports last month were down nearly 50 per cent., being only 22,813 tons as against 41,712 tons in August; whilst only 5,749 tons of manufactured iron and steel went abroad, as against 16,302 tons in August. Coastwise shipments of pig-iron last month amounted to 6,766 tons, as against 6,881 tons in August.

Coke.—The state of the coke trade still leaves much to be desired, but it is gratifying to hear of some further slight improvement. Supply to the furnaces is rather better, but some consumers are still receiving hand-to-mouth deliveries. Average blast-furnace quality is 33*s.* at the ovens, and low phosphorus sort, 35*s.* 6*d.* at the ovens. Foundry quality for neutrals is selling at 65*s.* f.o.b. Middlesbrough Dock, and gas-house coke for export is quoted 47*s.* 6*d.* to 50*s.*

COAL CONTROL OFFICE.—The Board of Trade has made an Order entitled the "Gas Coke Prices Order, 1918," fixing the price of gas coke and breeze used for industrial purposes. The Order comes into force on Monday next, the 7th inst. It contains provisions authorising the Controller of Coal Mines to suspend any of its provisions in any districts, or to vary the maximum prices in any cases of hardship.

FUEL ECONOMY.—A course of three public lectures, illustrated by lantern slides and experiments, on "The Principles of Fuel Economy in the Home," will be delivered at University College by Mr. A. H. Barker, lecturer in heating and ventilating engineering, on Wednesdays, October 9, 16 and 23, at 7 p.m. The lectures will be of a popular character; they are designed to meet the needs of householders who are faced with the problem of fuel economy. A leaflet giving a syllabus of the lectures may be obtained by sending a stamped addressed envelope to the Publications Secretary, University College, London (Gower-street, W.C. 1).

JAPANESE IMPORTS OF IRON AND STEEL IN 1917.—Imports into Japan of various steel products in 1917 were much larger than in 1916 and 1915, says *The Iron Age*. Plates and sheets imports were 296,816 tons, as compared with 159,881 tons and 77,569 tons in 1916 and 1915 respectively. Pig-iron and ingots are reported together as 235,221 tons, as against 243,182 tons and 173,883 tons in 1916 and 1915. Bars, rods and shapes totalled 221,243 tons in 1917, compared with 161,268 tons and 68,082 tons in the two preceding years. Rail imports were 50,671 tons; in 1916 they were only 4,344 tons, and in 1915 8,920 tons.

NOTICES OF MEETINGS.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, October 4, at 6 p.m., in the Meeting Hall of the Institution of Civil Engineers, Great George-street, Westminster, S.W., the Thomas Hawksley Lecture on "The Experimental Study of the Mechanical Properties of Materials," will be delivered by Dr. W. Cawthorne Unwin, F.R.S., past-president.

THE MINING INSTITUTE OF SCOTLAND.—Saturday, October 5, at 2.30 p.m., in the Heriot Watt College, Chambers-street, Edinburgh. Mr. R. W. Dron's paper on "The Occurrence of Coking Coal in Scotland," will be discussed; Mr. Stewart Chambers paper on "The Repair of a Circular Shaft of Small Diameter" will be discussed; a paper will be read by Mr. John A. Yeadon on "The Economy of Briquetting Small Coal."

BRITISH FOUNDRYMEN'S ASSOCIATION: LANCASHIRE BRANCH.—Saturday, October 5, in the College of Technology, Manchester, commencing at 4 p.m. Mr. Samuel Roe, of Oldham, will deliver the presidential address.

INSTITUTE OF MARINE ENGINEERS (INCORPORATED).—Tuesday, October 8, at 6 p.m., "Feeding and Circulating the Water in Steam Boilers," by Mr. John Watson (Member).

THE INSTITUTION OF HEATING AND VENTILATING ENGINEERS (INCORPORATED).—Tuesday, October 8, at 6 p.m., at the Holborn Restaurant, Holborn, W.C. (Duke's Salon), the annual general meeting will be held. The following papers will be read and discussed: Paper on "A New Method of Testing Heat Transmission from Radiators," by M. Kinoshita; extracts from the published report of Research Committee on "Transmission of Heat through Heavy Building Materials"; Report of Research Committee; (time permitting), discussion on paper read by Mr. E. Herring at the last February general meeting on "Our Coal Resources and their Future Economical Utilisation for Industrial and Domestic Purposes viewed from the Heating Engineers' Standpoint."

THE OPTICAL SOCIETY.—Thursday, October 10, at 7 p.m., at the Imperial College of Science and Technology, South Kensington. The following contributions will be submitted for discussion:—(*a*) "Sources and Magnitudes of Centreing Errors in a Sextant," by Naval Instructor T. Y. Baker, R.N. (Member of Council); (*b*) "Astigmatism-Interchangeability of Stop and Object," by Theodore Chaundy, M.A. (Member).

THE SHEFFIELD ASSOCIATION OF METALLURGISTS AND METALLURGICAL CHEMISTS.—Thursday, October 10, at 7.30 p.m. The opening paper of the Session will be read in the Assembly Room at the Royal Victoria Hotel by Professor H. C. H. Carpenter, F.R.S. (President of the Institute of Metals), entitled "Some Scientific Aspects of Steel Metallurgy."

THE ASSOCIATION OF ENGINEERING AND SHIPBUILDING DRAUGHTSMEN: NEWCASTLE BRANCH, TECHNICAL SECTION.—Friday, October 11, at 7.30 p.m., in the Connaught Hall, Newcastle-on-Tyne. A paper will be read by Dr. Allan, B.Sc., entitled "The Design of Ship's Lines and Some Considerations of Form."

DEPARTMENT OF AIRCRAFT PRODUCTION.—The Minister of Munitions has appointed Mr. A. E. Berriman, chief engineer to the Daimler Company, to be Deputy-Controller of the Technical Department of the Department of Aircraft Production of the Ministry, in succession to the late Professor Bertram Hopkinson, F.R.S.

PROPOSED TURIN-LYONS-BORDEAUX RAILWAY.—The British Chamber of Commerce, Paris, says that a committee, called "Switzerland Ocean," or 45th parallel, has discussed the execution of a project for a Turin-Lyons-Limoges-Bordeaux railway, to facilitate and increase the commerce relations of Italy and beyond with North and South America.

HONOURS IN THE NAVY.—A correspondent writing in the *South Wales Daily News* says that a comparison of the number of officers borne with the number of officers decorated with British Orders shows the astounding result (omitting fractions) that these Orders are awarded to—

One executive officer out of every	...	4
One accountant officer out of every	...	9
One medical officer out of every...	...	12
And one engineering officer out of every		23

The journal adds that by far the least favoured of the four big branches of the Navy are the engineers. Their history, since pre-Crimean war days, has been one long struggle to benefit their position and to obtain status and pay corresponding to their onerous and responsible duties. Such was the progress of their cause in the national conscience that the Admiralty in 1902, sooner than yield to the just claims of this line, decided to abolish it. The engineer officers of the future were to be drawn from the Osborne Cadets, either voluntarily or compulsorily, after a common course of training ashore and afloat. From that time no more entries of engineer cadets were made, and the old engineer line became moribund. This is probably the main reason why this line has been so unfairly treated in the matter of decorations by the admirals at Whitehall. There is no reason to propitiate a practically defunct line, as the necessity for attracting recruits to it no longer exists. As a postscript, it is illuminating to note that of the 49 awards of the Legion of Honour announced in the *Gazette* of the 28th of last month the admirals of the Admiralty have shared out 38 to officers of their own line, 6 to paymasters, 4 to doctors, and 1 to an engineer.

COKE-HANDLING PLANT AT THE BRADFORD ROAD GAS WORKS OF THE MANCHESTER CORPORATION.

CONSTRUCTED BY MESSRS. DRAKES, LIMITED, ENGINEERS, HALIFAX.

(*For Description, see Page* 367.)

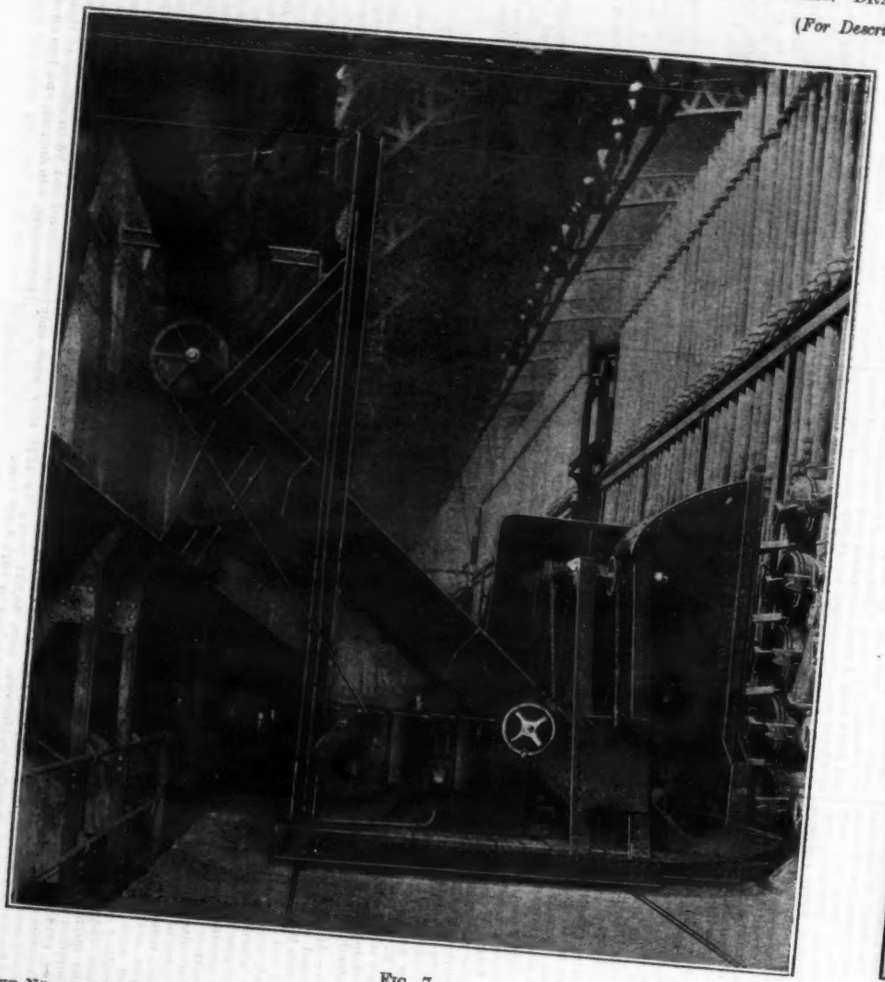


FIG. 7.

FIG. 8.

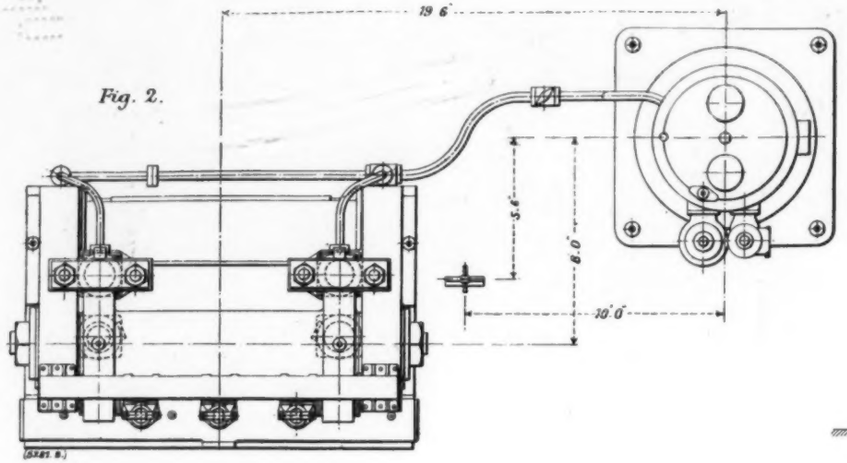
THE NÜSCHELER STAINED-GLASS STONE WINDOWS.—The new style of stained-glass windows which Richard A. Nüscheler, of Boswil, Aargau, Switzerland, first exhibited under the name of stained-glass stone windows, at the Swiss Exhibition, held at Bern in 1914, and which has since attracted considerable attention, may be described as a glass-mosaic set in a framing of artificial stone in such a way that the stone ribs either seem to form architectural elements of the window, or to mark the contours of the figures depicted. The large rose-windows of Gothic churches suggested to him the former idea; the latter suggestion came from the windows of the Königsfelden monastery near Brugg, in which the pieces of stained glass are held by ribs of plaster so shaped that the oblique faces of the ribs diffuse the coloured light. Thus the Nüscheler windows consist of a framing into which relatively small pieces of coloured glass, each only of one shade, are cemented like ordinary window panes; but the framing is itself part of the structure and picture, and the openings which are closed by the pieces of mosaic widen out inward. The process is patented. The original mould of the framing is a positive made in loam; a negative of this taken in plaster and strengthened at the back may serve for the making of many positives in an artificial white stone which is reinforced with iron like concrete. As the openings subsequently to be closed by the glass are not of large areas, the wind pressure is less to be feared than with wide expanses of glass in flat and narrow frames of lead and iron in the case of ordinary stained-glass windows. Strength and fire tests, conducted at the Swiss material testing station, have given satisfactory results, we see from the *Schweizerische Bauzeitung* of September 7. This issue illustrates some windows, roses as well as ordinary windows, made by Nüscheler for a new church built at Neudorf, near St. Gallen. So far as can be judged from these illustrations in black and white, the effects are decidedly pleasing, and one obtains much more than with ordinary stained-glass windows the impression of the picture, positive when sitting inside the church, and of its negative when seeing the window from outside; many old stained-glass church windows appear actually disfiguring when viewed from outside. Nüscheler does not apply shading to his glass by painting it over; where deeper shades are required than are obtainable with one sheet of transparent glass, he superposes two or three sheets. The oblique faces of the white stone ribbing soften the contrasts.

STEAM HYDRAULIC PLATE SHEARS.

CONSTRUCTED BY MESSRS. DUNCAN STEWART AND CO., LIMITED, ENGINEERS, GLASGOW.

(For Description, see page 385.)

Fig. 2.



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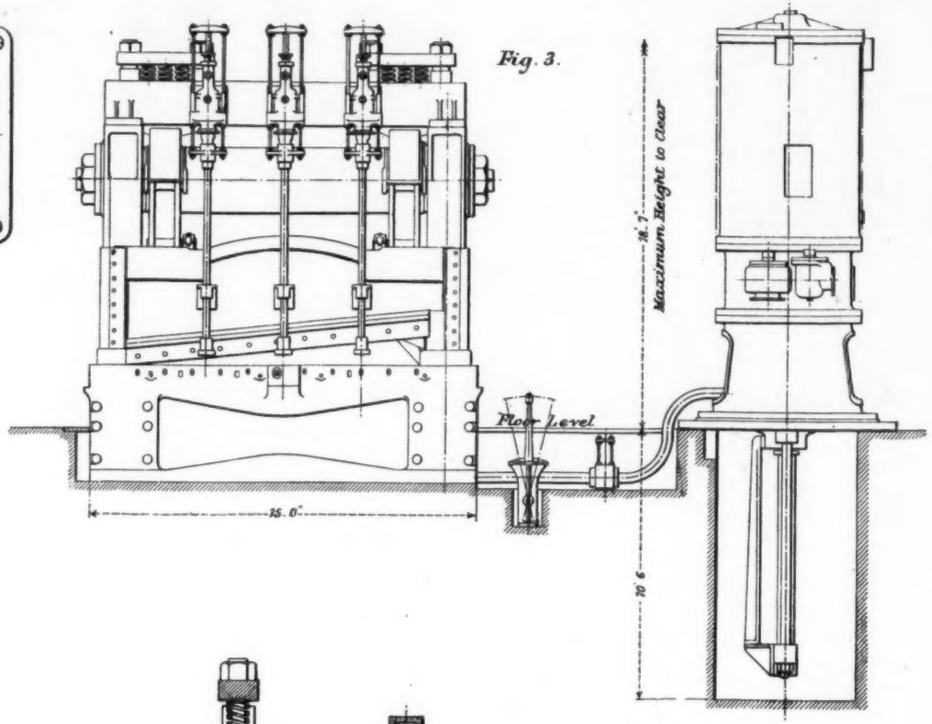

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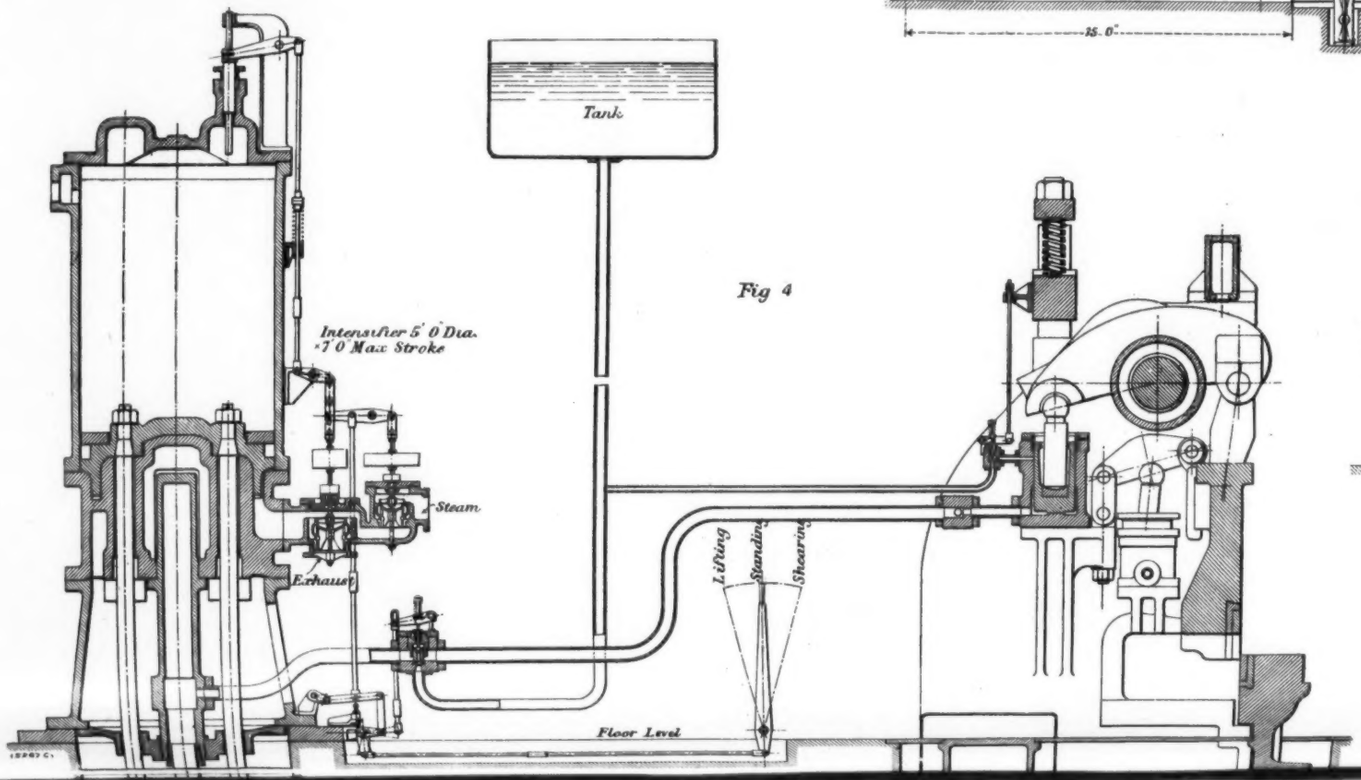

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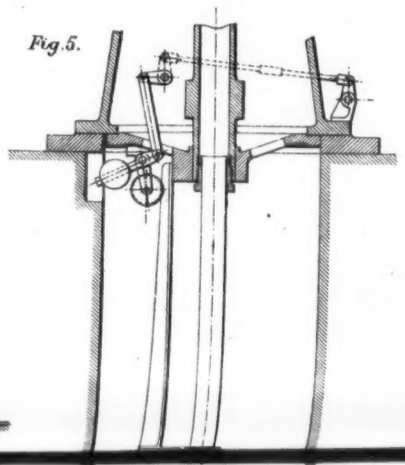

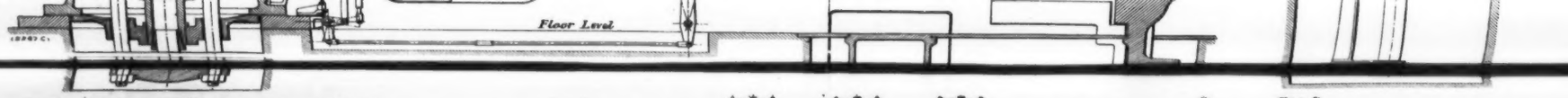

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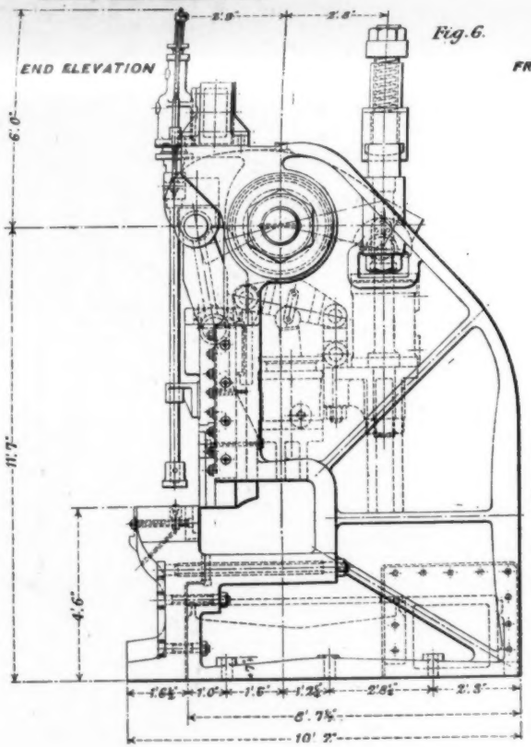

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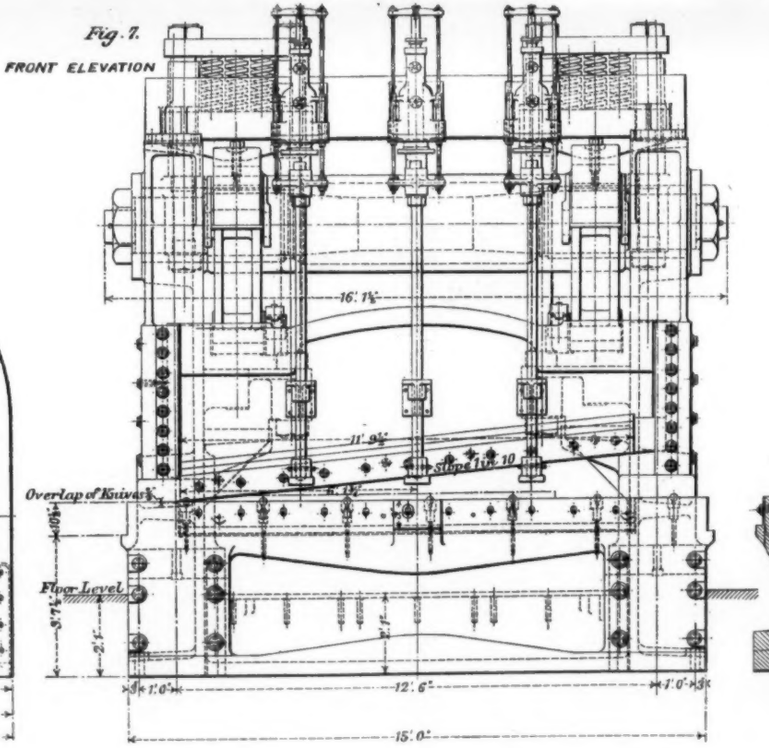

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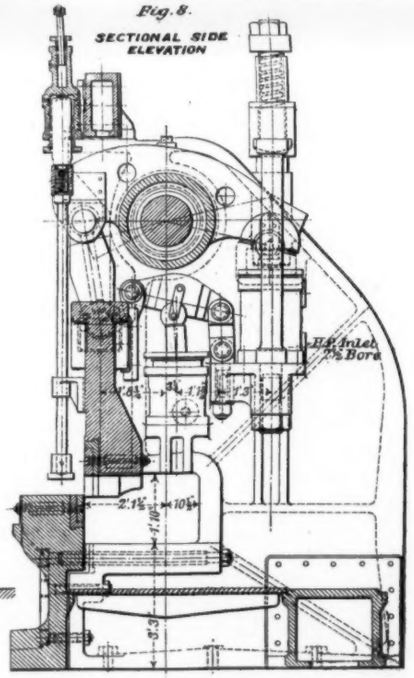

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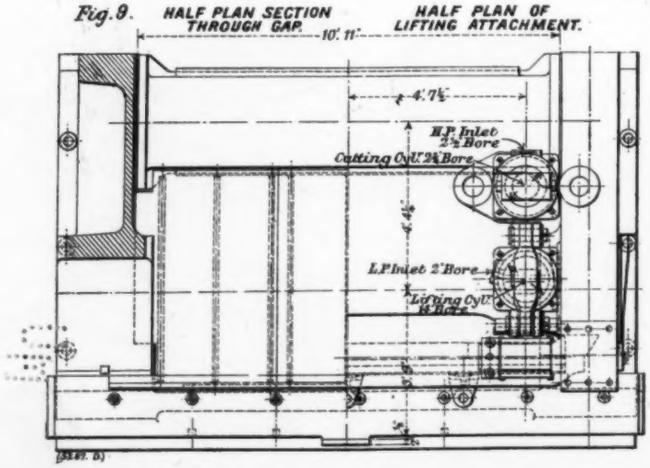


Fig.10.

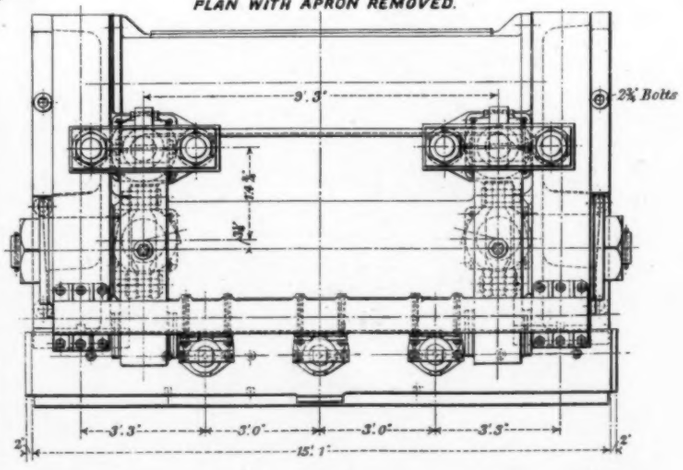
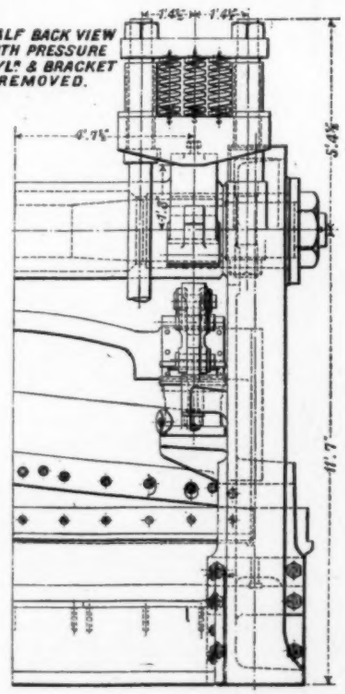


Fig.11.



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ADVERTISEMENT RATES.

The charge for advertisements is three shillings for the first four lines or under, and eightpence for each additional line. The line averages seven words. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than Monday morning.

SUBSCRIPTIONS, HOME AND FOREIGN.

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Foreign and Colonial subscribers receiving incomplete copies through newsagents are requested to communicate the fact to the Publisher, together with the agent's name and address.

All accounts are payable to "ENGINEERING," LIMITED. Cheques should be crossed "Union of London and Smith's Bank, Limited, Charing Cross Branch." Post-Office Orders should be made payable at Bedford-street, Strand, W.C. 2.

Offices for Publication and Advertisements, 35 and 36, Bedford-street, Strand, London, W.C. 2.

We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.

TELEPHONE NUMBERS—3883 and 8596 GERRARD.

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With a Two-Page Plate of a STEAM HYDRAULIC PLATE SHEAR.

NOTICE.

Owing to the recent Government restrictions, and to the enormous increase in the price of paper occasioned thereby, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal further from 8d. to 9d. per copy. This increase dates from and includes the issue of Friday, March 1, 1918. The change will not apply to unexpired subscriptions. The revised rates for new subscriptions are given in the adjoining column.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper and the consequent shortage of supplies, Newsagents will not have copies for chance customers; therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 375.

ENGINEERING.

FRIDAY, OCTOBER 4, 1918.

THE WORLD'S STEEL TRADE.

BEFORE the war the world's demand for steel goods, including engineering products, was increasing more substantially than its demand for any other important class of commodities. What will be the position after the war? In the last thirty years of peace the world's consumption of iron and steel, reckoned in terms of pig-iron, increased from about 20,000,000 tons a year to about 75,000,000 tons. Steel was being put to an ever-increasing number and variety of new purposes. More and more was it being substituted for wood and stone. But, from a British point of view, the iron and steel trade position was far from satisfactory before the war. British industry was doing little more than marking time, whilst the trades of other countries were going forward rapidly. Relatively and comparatively we were losing much ground. In thirty years the world's *per capita* consumption of iron—its demand for iron and steel goods, per head—increased by 150 per cent. Our contribution to that great increase was nil. We did not increase our *per capita* output by 1 per cent. The Americans increased their *per capita* production by nearly 300 per cent. The Germans increased theirs by 200 per cent. How shall we progress after the war? We cannot expect to approach the United States in volume of production. The Americans have vastly more coal and iron ore than we have, and they have a far bigger home market. But when it comes to the exportation of steel goods we ought to reign supreme. Our chief rivals, the Americans and Germans, are almost self-contained nations, producing for themselves nearly all the food they need. Requiring to import very little food, our competitors have no really great economic need for export trade in manufactures, such as those of steel. But to us a huge export business in manufactures is vital and imperative. We import more food and other raw materials than any other nation. For this reason alone we need to do the most export trade in manufactures. This point is of supreme importance, but it is hardly ever realised or mentioned by Englishmen. It is not sufficient that we should simply beat other nations in manufactured exports; we ought to be far ahead of even the strongest rival in this particular line. Not only do we depend upon abnormal exports of manufactures to balance our abnormal food imports, but by virtue of our peculiar resources our unique geographical situation, and our Colonial possessions, we are pre-eminently fitted to conduct the largest trade in steel exports.

To begin with, we are the only great nation with coal and iron ore supplies, manufacturing plants and shipping ports, practically side by side. Clearly we have been ordained by Nature to be a great steel-producing and exporting country. We have been lavishly endowed with all the essentials. Next, we possess—or did possess, before the war, and there is no reason why we should not again soon possess after the war—as much shipping as all other nations put together. Here, again, we have been cut out by Nature to be the first external shipping country. In some respects we are not nearly so well off as other countries; but for the economical production and shipment of steel goods we are better situated than any other nation. This is a simple and indisputable fact, and we should recognise it and act upon it. In the next place, we have more Colonies and Dependencies needing steel goods than all other nations combined. Similarly, we have had more capital invested in foreign railways and other undertakings requiring steel than any other nation. All these circumstances should have combined to give us by far the most export trade in steel. But what was the position? Thirty and forty years ago we did, in fact, do as much export trade in iron and steel as all other nations put together. But before this war broke out one nation, the Germans, had by themselves got ahead of us. In the last half-year before the war Germany exported 1,000,000 tons of iron and steel more than Great Britain did—Germany, with much less conveniently-deposited minerals, a much inferior shipping position, with less than one-third as many ships as we possessed, with practically no rich Colonies, and with nothing like our economic need of export trade, for Germany grew within her own borders 95 per cent. of the food she consumed. Less than fifteen years before the war we were ahead of Germany in this line to the extent of exporting 3,500,000 tons of iron and steel a year to Germany's 750,000 tons. But in 1913 the Germans exported 6,000,000 tons against our 5,000,000 tons, and in the first half of 1914 they exported 3,500,000 tons against our 2,500,000 tons. But for the war, there can be no doubt, Germany would soon have swept us clean off many of the world's markets, for as a nation we absolutely refused to wake up and face the facts and look after our own interests.

Now what of the future? We have seen that the war, so far from creating the depression that so many predicted, has called for all the iron and steel that the producing nations can provide. Capacity has had to be increased to cope with the war demands. Meantime, few of the ordinary demands can be met. The world is simply hungering for steel. Germany, the greatest exporter before the war, has been practically out of business for more than four years. British exports have been curtailed until now they are on a scale below one-third the pre-war level. Belgium, France and other smaller European steel-exporting countries have done practically nothing in this line since war broke out. And the United States has not been able to make up anything like the total deficiency. Before the war American exports were not more than about 2,000,000 tons a year. Up to her active entry into the war last year the United States managed to increase her steel exports up to a 6,000,000-ton level, but this exportation is now declining under the pressure of demand for munitions. The world's shortage of commercial iron and steel, reckoned only on the basis of pre-war exports, must now, for the four years of war, be not less than 35,000,000 tons. Taking German exports at only 6,000,000 tons a year, four years of suspension means a loss of 24,000,000 tons. Taking our exports at 5,000,000 tons (pre-war figures) and allowing that we have averaged half our ordinary trade over the full war period, this is a further loss of 10,000,000 tons—four years at 2,500,000 tons instead of 5,000,000 tons. America's increased exports will not have done more than balance the loss of Belgian, French and other European trade in this line. The outbreak of peace will find the world with all these arrears of what we may call ordinary constructions and renewals to make good, besides the damages and wastages of war. To-day there is a world's famine in ordinary steel and steel goods. Every day of the war is intensifying it. Peace will bring a tremendous and long-sustained demand for railway, ship and other building purposes, and a general renewal of machinery and tools. We have already noted that before the war the world's appetite for steel was rapidly increasing. There is no sign of any check in the growth of this appetite.

Here it may be remarked that the world has to

depend—and is long likely to have to depend—mainly upon three nations for its iron, steel and engineering goods. The United States, Germany and Britain between them are responsible for about 80 per cent. of the world's total, and this percentage, or proportion, is not likely to vary much for many years, if not decades. It will be long before even the most ambitious and promising of the newer and smaller steel countries can do much to disturb the balance at present in favour of these three great steel nations. And Britain, with her capacity so largely increased during the war, and in view of certain other new conditions created by the war, should easily regain and retain first place as an iron and steel exporting nation. The war, indeed, should prove the very salvation of the British steel trade, not only by inducing us to adopt improved methods and make vast extensions, but by arresting the worst forms of German competition and giving our products a preference among our friends.

It is a remarkable and striking testimony to the fundamental soundness of the British iron industry that, whilst production in Germany is admitted by the trade journals of that country to be about 5,000,000 tons a year below the pre-war level, and whilst even the vast United States is having the greatest difficulty to improve upon its best peace-time production, we in this country are beating our best peace record by 50 per cent. The outbreak of peace will find us with a works capacity that will enable us to be practically independent of the 2,000,000 tons we imported before the war, and to produce a surplus of about 8,000,000 tons of iron and steel goods a year for export, against the 5,000,000 tons exported before the war. This is a striking and significant fact. It is only natural, of course, that our manufacturers, with their ordinary exports cut down by nearly 75 per cent., should be chafing a little under the restrictions, and should be somewhat uneasy about the trend of wages, coal prices and other productive costs—not to mention the disinclination of the Government to pronounce a clear-cut policy for after the war—but there is the satisfaction of being able to reflect that not only is our biggest pre-war rival, Germany, out of business altogether for the period of the war, and likely to be boycotted after the war, besides her productive capacity being then most probably smaller rather than larger, but that wages and other costs are increasing in Germany, America, and elsewhere much as they are here, whilst from the United States, our chief competitor next to Germany, we shall never experience the fierce undercutting—the subsidised dumping—that characterised Teutonic trading. Wages alone in the American steel industry have been increased by 95 per cent. since 1915, and are now exactly 300 per cent. higher than they were twenty years ago. In Germany iron and coal miners' wages have been increased since the war started by from 84 per cent. to 96 per cent.—much about the same as the wages of our miners. Munitioners' wages in Germany have not risen to such levels as in Britain, but that general costs of production have advanced by quite as much in that country as here may be gathered by the fact that between August, 1914, and August, 1918, the following price increases have been made in Germany: Hematite pig-iron, from 78*s.* 6*d.* to 223*s.*; ingots, from 87*s.* 6*d.* to 192*s.* 6*d.*; bars, from 95*s.* to 235*s.*; and plates, from 98*s.* to 275*s.* per ton.

To sum up, the world's coming peace demand for steel goods will be greater than even the current abnormal war demand, and this country, with its unique facilities for manufacture and exportation, should beat all rivals in neutral markets. Germany's productive powers will be to some extent impaired, for her losses of men are such as cannot be balanced by any mechanical improvements, or the employment of women; her agents and goods will be to some extent boycotted, or penalised, whilst preference will be accorded British products in many markets. Regarding United States competition, we may be sure that American manufacturers will find such a huge and profitable market at home—the domestic requirements of the United States are, for special reasons, much beyond those of any other country—and their productive costs so high, that they will not offer us keen competition in the export race. Foreign competition is not, of course, to be ignored; but our resources are such that we can easily take first place as an exporting nation, if only our trade unionists will be anything like reasonable, if our manufacturers will organise, and if our statesmen will afford our industries fair play.

THE EXPLOSIBILITY OF COAL DUST AIR MIXTURES.

The United States Bureau of Mines has recently resumed its laboratory investigations on the inflammability of coal dust, because it was observed that dusts of too low inflammability to be ignited by the laboratory tests previously used were nevertheless capable of propagating violent explosions in the mine. The sensitiveness of the laboratory method has hence been increased, and the new apparatus is described in Technical Paper 141, by J. K. Clement and J. N. Lawrence. The new explosion globe is a glass vessel of 1,400 cub. cm. capacity provided with tubulures at the top and bottom. The ignition tube is a horizontal tube of hardened "lavite"; the tube is wound with platinum wire, embedded in alundum cement, the whole fitting into a tube of sheet platinum, 0·1 mm. thick; the tube is held in the middle of the globe by two platinum wires, 0·4 mm. in diameter, which are fused to the ends of the heating coil. Underneath the globe is a funnel covered by a sheet of copper wire-gauze through which a cloud of coal dust is blown against the hot tube by admitting compressed oxygen into the bottom of the funnel. The temperature of the tube is determined with the aid of a platinum/platinum-rhodium couple; the alloy wire is soldered to the platinum in the middle of the tube, the platinum wire to a point about 3 mm. away. The pressure generated by the explosion is recorded by a Crosby indicator. The weight of coal dust, air-dried and passed through a 200-mesh sieve, used in an experiment is generally 100 milligrammes; in cases of low inflammability the weight is raised to 300 milligrammes.

Plotting the pressures developed by the explosive combustion of these samples as ordinates against the temperatures as abscissæ, it was observed that the curves became practically horizontal at 1,200 deg. C., the maximum temperature used, if they had not already done so at lower temperatures. The first series of experiments was made with five different coals and a lignite, ranging in percentages of volatile matter from 44 down to 16·75, and in fixed carbon from 47·5 up to 78, in the order: sub-bituminous coal from Utah, a lignite from North Dakota, bituminous coals from Pennsylvania and from Alabama, semi-bituminous coal from West Virginia. The ash contents, 4·7 per cent. to 10·8 per cent., did not fit into this order, the lignite containing the greatest amount of ashes. Pressures to speak of were hardly developed by any explosion below 750 deg. C., that is to say, those pressures barely exceeded 1 lb. per square inch; at temperatures above 1,100 deg. the pressures decreased in the order stated, but at 1,000 deg. the Alabama and Virginia coal hardly recorded any pressure. The lignite gave the highest pressure next to the Utah coal; but the lignite was air dried (10·6 per cent. of moisture), and the samples indicated a pressure of 15·4 lb. per square inch, whilst the moist sample as received (41·3 per cent. of moisture) only gave 0·9 lb. As nearly all lignites mined in the United States carry high percentages of moisture they cannot be regarded as very inflammable. Mine tests subsequently made confirmed these laboratory tests also as to the relative safety of lignite dust. In standardising the laboratory methods dust are classified as (1) dusts which, when suspended in air, may be ignited by a flame and give rise to an explosion; (2) dusts which, suspended in air, cannot be ignited by a blown-out shot, by burning gas or an electric arc, but which may propagate an explosion already set up in a cloud of more inflammable dust or in an explosive gas mixture; (3) dusts that will not propagate an explosion. It would, of course, be very valuable if we could decide by laboratory experiments to which group any dust or mixture of dust with shale would belong, and the Bureau experts consider that they can decide that by their tests. In this work, the term "ignition limit" is used to designate the highest percentage of shale dust with which a given coal dust can be mixed and yet be ignited by the flame of a blown-out shot of black powder and give rise to an explosion; the "propagation limit" indicates the highest percentage of shale dust which would still leave a coal dust capable of propagating an explosion. In the classification mentioned the ignition limit falls on the boundary between classes (1) and (2), and the propagation limit between classes (2) and (3). These limits have been determined, within about 5 per cent. or 10 per cent., in the experimental mine of the Bureau for a number of typical dusts; the coal dust of that mine itself, *e.g.*, has an ignition limit of 59 per cent. of shale, and a propagation limit of 73 per cent. of shale. The shale contains 99 per cent. of incombustible matter, and both the shale and the coal are ground to 200 mesh.

The explosive gas added to the air in some laboratory tests is natural gas from Pittsburg, containing 84·7 per cent. of methane, the rest being ethane propane, butane and 1·6 per cent. of nitrogen; the percentages of gas added are 0, 1, 2, sometimes 3. With 0 per cent., 1 per cent., 2 per cent. of gas Lucerne mine coal had an ignition limit of 54 per cent., 61 per cent., 68 per cent. of shale; Eccles mine coal gave 35 per cent., 40 per cent., 53 per cent., a Maryland mine coal required only 5 per cent., 12 per cent., 25 per cent. of shale. The propagation limits found in mine tests were in good agreement with the laboratory values; the ignition values derived from mine tests were decidedly higher than the laboratory values, moreover, particularly in the case of the Maryland coal, where the mine tests yielded limit percentages of 28, 40, 50, instead of the 5, 12, 25 just stated. But the trends of the curves were the same, however, and there is thus a definite relation between the inflammability of coal dust as indicated by the pressure observed in laboratory experiments and the limits of ignition and propagation found in the mine.

Experiments made with 600 coals taken from 21 of the States of the United States and also from two provinces of Canada confirm these general conclusions. Further tests, however, also show the paramount importance of the size of the dust particles, and one is rather astonished in the first instance that this point is only discussed in the last portion of the paper. Dust from Pittsburg coal, when so fine that from 85 per cent. to 90 per cent. passed through a 200-mesh sieve—the sieve generally used for preparing the samples—required an amount of shale dust equal to four times its own weight to prevent propagation of flame; when the dust was coarser, and only 40 per cent. of the coal passed through this sieve, not more than three times the weight of shale was required for the purpose, and with 20 per cent. the necessary weight of shale went down to twice the weight of the coal. These facts prove the desirability of making screen tests of the road-dust samples received for inflammability tests so as to obtain more accurate information than the laboratory tests afforded as to the amount of shale dust needed to prevent ignition or propagation of an explosion. Any error due to this cause is on the side of safety, however, since the laboratory test generally indicates a greater inflammability than may actually exist. As regards the moisture of natural dust the possible error of the laboratory tests, which are conducted with air-dried samples of about 10 per cent. of moisture, is again on the safe side; since the coal in the mine generally contains decidedly more moisture. These considerations add considerably to the value of laboratory tests which one might otherwise question.

THE POSITION OF AIRSHIPS IN THE FUTURE OF AERONAUTICS.

The success recently achieved by large aeroplanes, and the comparatively poor results obtained by the airship as a war machine, has had the effect in aeronautical circles of creating a state of mind wherein the aeroplane is considered as the only air machine worthy of development for commercial or other purposes. In an endeavour to consider the question in true perspective, particularly in connection with the airship and its use for com-

mercial work after the war, it seems desirable to put forward the following views and make some comparisons of the qualities and performances of aeroplanes and airships.

First: in order to make a fair comparison a correct idea of the relation between airships and aeroplanes in regard to size should be obtained. An aeroplane is considered big and to represent to the minds of those who have only dealt with aeroplanes a great achievement when its gross weight or lift is in the region of 6 tons: in fact 14 tons probably represents the limit of size that has yet been attempted with any degree of success. In comparison with an airship 14 tons is quite small; in fact, airships of five times this gross weight have been in use for some time in Germany, and it is quite possible that airships of 100 tons weight are on the stocks at the present time. Moreover, unless some radical changes in design are brought about in connection with aeroplanes, it is quite possible that an airship of 200 tons gross lift could be constructed with success much more easily than an aeroplane of 30 tons gross weight.

The effect of the comparative ease of designing and constructing a really large aerial machine as represented by an airship is seen greatly to advantage when considering the question of carrying capacity or useful lift. It is a remarkable fact that as a general rule the proportion of useful lift to gross lift is about the same for both aeroplane and airship of equally good design, being on an average about 33 per cent., ranging between 25 per cent. to 45 per cent. according to the quality of the design in both cases. Machines of special design when useful lift or speed is gained at the expense of some other attribute are, of course, ruled out of this comparison, otherwise one might quote an airship of small power and speed with a very high percentage of useful lift in comparison with a fast high-powered aeroplane with a very small proportion of useful lift. This fact puts the airship in a very favourable position as regards weight carrying, particularly for commercial purposes, since whereas a large aeroplane of 6 tons gross weight would only have a useful carrying capacity of 2 tons, a 60-ton airship can carry a useful load of 20 tons. Useful load in both cases is taken as representing fuel, crew, oil and cargo of commercial or military value.

The airship is generally referred to by those who would limit aerial development to aeroplanes as a big clumsy gasbag, but when a proper comparison is made of airship and aeroplane of the same gross lift or weight, it will be seen that there is no great difference in dimensions, particularly so if we try to compare an aeroplane designed to have, say, a gross weight of 60 tons with that of a 60-ton ship. For instance, suppose a 60-ton super "Gotha" were designed on the same lines as the present type—the area of the planes would have to be $\frac{60}{3{\cdot}25}$ times that of the present Gotha, and therefore would be:

$$958 \times \frac{60}{3{\cdot}25} = 17{,}700 \text{ sq. ft.}$$

since the lift is proportional to the plane area, and an ordinary Gotha weighs 3·25 tons, its plane area being 958 sq. ft. The overall dimensions on the bases of the linear dimensions being proportional to the square root of the area and thus of the gross weight would be:—

$$\text{Span } 78 \times \sqrt{\frac{60}{3{\cdot}25}} = 334 \text{ ft. span.}$$

$$\text{Length } 41 \text{ ft.} \times \sqrt{\frac{60}{3{\cdot}25}} = 175 \text{ ft. length.}$$

$$\text{Height } 12{\cdot}75 \times \sqrt{\frac{60}{3{\cdot}25}} = 59{\cdot}5 \text{ ft. height.}$$

It is admitted that it would be possible to considerably improve upon these figures by making multiplane types which will decrease the lateral dimensions and increase the height; yet, when we consider that the dimensions of a 60-ton Zeppelin airship are only 650 ft. long, 79 ft. wide and 92 ft. overall height, it will be seen that the airship is at no great disadvantage in this respect. Further, if we reckon floor space occupied as length by breadth, the floor space occupied by the 60-ton plane is about equal to that occupied by the ship:—

Aeroplane	...	334 ft. × 175 ft.	= 58,500 sq. ft.
Airship	...	650 ft. × 79 ft.	= 51,200 sq. ft.

The assumption of similar design for the 60-ton aeroplane and a 3½-ton plane is of course purely hypothetical, but the foregoing remarks will, it is hoped, be sufficient to show that it is unfair to classify an airship as cumbersome, as compared with planes, without due regard to lifting capacity.

If we consider planes or ships of very large gross lifting capacity the advantage of smaller dimensions will ultimately be with the airship as the lifting capacity of the ship increases with the cube of the linear dimensions of the hull and that of the aeroplanes as the square of the linear dimensions of the planes. For instance, the dimensions of a 200-ton airship would only be 975 ft. long, 118 ft. diameter, and about 138 ft. overall height, whilst the dimensions of any aeroplane designed on present lines would greatly exceed these dimensions, even if such an aeroplane were possible to construct.

As regards air resistance and power required, the large airship shows to great advantage over the large aeroplane. This advantage arises out of the two facts: (1) That in an aeroplane a large proportion of the power is required in order to obtain the dynamic lift as apart from the direct resistance of the aeroplane to motion through the air, whereas an airship obtains its lift without expenditure of power. (2) The resistance of the hull, or lifting body, which is the greater portion of the resistance of a large ship, is in the case of the ship proportional to $W^{\frac{2}{3}}$ and in the aeroplane proportional to W, where W equals gross lift, and therefore, the greater W the less the resistance of the lifting body of the ship in proportion. In the larger sizes the aerodynamic resistance of the planes alone would be much greater than the resistance of the whole airship.

In connection with (1) we may state that a well-designed aeroplane wing has a lift drift ratio of 1 to 15 and for a biplane construction 1 to 14, which means that the resistance to motion is 1/14th of the weight sustained or about 7 per cent. This is almost a constant quantity for whatever speed the plane is designed. To this must be added the resistance of all other parts of the machine an amount generally about equal to this making 14 per cent. in all of the gross weight.

Now a modern airship of 60 tons displacement has a resistance of about 5 per cent. of its gross weight at 65 m.p.h. and it will, therefore, be seen that the power required for a 60-ton aeroplane would be 2·7 times as great if designed for the same speed. Even at 90 m.p.h., which is a reasonable speed for a large aeroplane, the total resistance of the airship would only be 10 per cent., whereas the aeroplane would have a resistance of 17 per cent. of its gross weight at this speed. It must be admitted, however, that in order to carry the necessary power on a ship, to obtain this latter speed an undue proportion of useful lift would have to be sacrificed. The figures for the airship quoted above are obtained from the particulars of Zeppelin "L. 33," the power being taken at 1,500 h.p. and the speed at 65 m.p.h., and due allowance being made for propeller efficiency, &c., of 75 per cent. overall.

The aeroplane figures may be confirmed by calculating the resistance from the best gliding angle obtained by aeroplanes. The best gliding angle is generally about 1 in 8, and therefore the resistance at the gliding speed is about ⅛th or 12·5 per cent. of the gross weight. The speed when gliding at the best angle is however only about 0·7 to 0.8 of the maximum speed of the plane, and it will therefore be seen that the 14 per cent. quoted above is really low and the advantage of the airship is therefore greater in this respect. If we use Lanchester's results, i.e., "that at the most economical speed the aerodynamic resistance is equal to the direct resistance," and also "that the most economical speed is the speed at best gliding angle" we have:—

Resistance at maximum speed

$$= \frac{12{\cdot}5}{2} + \frac{12{\cdot}5}{2} \times \left(\frac{1}{7{\cdot}5}\right)^2$$

$$= 17{\cdot}35 \text{ per cent.}$$

In this calculation the aerodynamic resistance is taken as being the same at both gliding speed and maximum speed and therefore equal to half the total resistance at gliding speed. This is not strictly true, and gives a result rather too high; actually 16 per cent. is more correct.

This question of power required for a given weight or size of aerial machine, will no doubt prove to be a most important consideration in the future development of aeronautics. It will be seen that in the light of present day knowledge, airships will always be superior to aeroplanes in this respect, particularly when we remember that Lanchester after carefully considering the question of the limit of possibility in this respect for aeroplanes gives such a limit as being possibly 10 per cent. at 90 miles per hour.

It is generally assumed that the aeroplane is essentially a much speedier aerial machine than a airship. We have seen however, in the foregoing paragraph that for the same speed a greater proportion of power is required for a large aeroplane than for an airship of the same gross weight. We also note, that, whereas in the case of the ship the proportional resistance or traction coefficient becomes less as the size increases (and consequently speed can be increased with size), we have at present, no reason to believe that large aeroplanes will be speedier than small ones: in fact, rather the reverse. There is every reason to believe that airships of 30 tons and over can be constructed having a speed of 80 miles per hour and a useful lift of 40 per cent. of the gross weight, which compares favourably with any aeroplane that may be proposed having a gross weight of anything approaching this figure.

As regards duration of flight, it should require no particular demonstration to show that the airship holds the field as regards duration both with respect to time or distance. The chief reason for this lies in the capability of the airship to cruise at quite a moderate speed with a very small proportion of its total horse power in use. The aeroplane as we know it must of necessity always expend the greater portion of its available horse-power in order to maintain itself in flight, and can only keep in reserve the portion that is required for climbing purposes which may be 30 per cent to 40 per cent., and even this can only be done in good weather when rapid variations in wind velocity are not prevalent.

An airship may fly at half-speed with an expenditure of only about one-eighth of its total horse-power, as the traction coefficient at low speed is very small, whilst an aeroplane must always use sufficient power to maintain its dynamic lift. This consideration is bound to prove of considerable importance in the commercial aeronautics of the future.

There is no doubt as regards height attainable, the aeroplane will always hold considerable advantage over the airship. Provided means are fitted on an aeroplane, as they undoubtedly will be, to maintain the power of the engines and the efficiency of the propellers at high altitudes there would appear to be no practical limit to the height that may be reached. In the case of the airship, however, available lift must always be sacrificed if high altitudes are to be attained. The limit of height is reached when all ballast or equivalent is disposed of, and the quantity of gas is just sufficient to maintain the ship in equilibrium.

The practical limit would appear to be about 15,000 ft. and even then the ship would require to have almost 50 per cent. of its gross weight available as ballast or equivalent unless the ship is supported by dynamic lift afterwards. The latter procedure is possible and is, in fact, carried out in practice by swivelling propellers, or by keeping the ship under way until actual landing.

However, for commercial purposes the question of height attainable is quite a minor point, and unless particular atmospheric conditions are to be encountered or made use of, 5,000 ft. would be all that is really necessary.

A good deal of adverse comment is often levelled against airships by referring to the difficulty of landing and generally handling the ships on the ground. This difficulty will no doubt, gradually be overcome by the provision of mechanical aids for this procedure. In addition whilst the landing of an ordinary aeroplane is comparatively easy, there is no doubt that, as the sizes of aeroplanes increase comparable to the size of large airships, it is quite possible that the difficulties of landing and ground

manœuvring will increase to such an extent that the airship may become the easier proposition, particularly when it is considered that the ship can always be brought to a standstill in the air before landing is attempted, but if a 60-ton aeroplane must land at something over 60 miles per hour there is likely to be considerable more difficulty than with one, say, of 3-tons weight.

The provision of sheds for the purpose of housing airships is, no doubt, a considerable obstacle to their development. When, however, we consider the question in the light of possible future development of landing grounds or harbours, and the satisfactory solution of the problem of mooring airships safely in the open, it is doubtful whether there will be much greater difficulty than with larger aeroplanes of comparable dimensions.

The greatest objection to the development of airships is no doubt, the hydrogen problem. The large expenditure involved in the manufacture, storage and upkeep of supplies and necessary plant in order to keep the ships inflated and replenished with gas would seem prohibitive.

One great source of trouble and expense is now being eliminated. Owing to imperfection of the gasbags it was formerly necessary to refill with gas at frequent intervals in order to replace impure gas. We have now reached a stage where it will be possible to use one charge of gas per year, with, of course, the necessary replenishing to replace the slight leakage and loss when gas is discharged during flight. The danger of fire becoming disastrous as a result of the use of hydrogen may in time be eliminated by developing the use of an inert gas such as helium, but this is not likely to become a practical proposition for some time.

The Institution of Locomotive Engineers (London).—We are informed that on the 29th inst. Mr. Paterson, district locomotive superintendent of the Lancashire and Yorkshire Railway, Low Moor, Yorkshire, will read a paper on "District Supervision of the Locomotive Department of a British Railway," and a discussion will follow. Mr. Paterson invites full discussion, and members and their friends are cordially invited to take part. The meeting will take place in the Philosophical Hall, Park-row, Leeds, and will commence at 7 o'clock.

Trade Scholarships for Boys, 1918.—The London County Council offers about 260 trade scholarships to boys between the ages of 12½ and 16 years whose parents are resident in London. The scholarships provide free education (with maintenance grants ranging from 6*d*. to 15*s*. a year) for one, two, or, in certain cases, three years at trade schools approved by the Council. The instruction provided at these schools is designed to enable boys on leaving school to take up either apprenticeships or employment in skilled trades. Instruction is given in motor-body building, the engineering and allied trades, building trades, furniture and woodwork trades, book production, silversmithing, photo-engraving and photo-process work, &c. Application forms (T.2/258) and full particulars of the scholarships may be obtained from the Education Officer (T.2), L.C.C. Education Offices, Victoria Embankment, W.C. 2, to whom all applications must be forwarded not later than Saturday, the 12th inst.

The Dunlop Endowment and Education Scheme.—The conclusion of the first term of the Dunlop Rubber Company's educational scheme and the inauguration of a staff endowment scheme were celebrated on Friday, September 6, at the Birmingham Temperance Hall. Mr. F. C. Baisley explained the schemes and pointed out that in the past industry and commerce in this country had been handicapped through the greater percentage of those employed being unable, for want of sufficient education, to use their abilities to the best advantage. The Dunlop scheme was essentially an encouragement scheme. It afforded facilities for education and provided the strongest possible inducements to study in the shape of continuous promotion, constantly increasing salary, the assurance of a satisfactory career for life and the benefit of an endowment at the age of 55. Some of the company's occupations called for the employment of men and women of high educational attainments, and positions were held by Doctors, Masters and Bachelors of Science and Masters and Bachelors of Arts. Every one of the executive directors of the company and most of the directors of the subsidiary companies had been promoted from the management. The endowment scheme was provided entirely at the expense of the company. The amount of the endowment depended upon the length and form of service between the ages of 20 and 55, and was adjusted yearly. The highest amount guaranteed by assurance was 3,000*l*. In the education scheme advantage was taken of the Municipal Educational Institutions, and provision was made not only for intermediate and higher education, but also for those who required preparation for admission to these studies.

LITERATURE.

Methods of Measuring Temperature. By Ezer Griffiths, D.Sc., Assistant in the Heat Department of the National Physical Laboratory. With an Introduction by Principal E. H. Griffiths, F.R.S. Illustrated. London: Charles Griffin and Co., Limited. [Price 8*s*. 6*d* net.]

Within recent years pyrometers have increased greatly in accuracy and convenience, and consequently have come into very general use in a large number of industrial operations where high temperatures are involved, and particularly in those where correct adjustment of temperature is essential to success. Progress has not been so rapid as it should have been, for too much reliance is still placed on so-called practical tests, the use of which may be justified in pottery production, but outside that limited industry cannot be commended. This trustfulness in long-trained experience is possibly strengthened by the knowledge that trouble has arisen when new methods have been introduced, forgetting that this trouble may be traceable to the use of a form of apparatus unsuited to the purpose to which it has been applied, or to the neglect of some precautions for which proper provision has been made in construction. Such a book as this provides precisely that information, which would prevent such untoward results, and secure the highest degree of accuracy. It is particularly suited to guide those who are in control of industrial processes, and at the same time it can be consulted in the laboratory or where the measurement of accurate temperature is necessary.

But though carelessness or indifference may fight against the adoption of scientific methods of pyrometry, it must be admitted that the existing mistrust, or neglect, of rigorous methods is in some measure to be attributed to the confusion occasioned by the discordant temperatures that different authorities have assigned to the same phenomena when high temperatures are concerned. The varied values quoted for the temperature of the positive crater of the electric arc have been regarded as evidence of untrustworthiness in experiment, and the impossibility of maintaining a uniform scale throughout a wide range. Here, again, the author does excellent service by insisting on the degree of reliability that can be placed on modern gas thermometer work, emphasising within what limits and under what restrictions an adopted scale can be regarded as continuous, and providing a standard to which all heat measurements can be directly referred. The measurement of heat is accompanied by peculiar difficulties. The international scale of temperature, based upon the expansion of hydrogen, which affords an excellent definition of a degree Centigrade, cannot be carried by direct measurement further than about 600 deg. C., because no satisfactory containing vessel has yet been found. Nitrogen being less active, but also a less perfect gas, permits direct measurement to be carried to about 1,200 deg. C. At this point inference or extrapolation begins, and though there is evidence —evidence that the author sets out clearly and cogently—that uniformity of scale is maintained with quite unimportant deviations to perhaps 1,550 deg. C., the melting-point of palladium, it must be remembered that in the use of these larger figures we are dealing with an independent system, whose connection with that used in recording lower temperatures is not severely established.

It is a matter for congratulation in the history of thermometric registration that advance has been so rapid and so satisfactory. Principal Griffiths, in an interesting introductory note reminds us, that thirty years ago, the boiling-point of sulphur was not known within 4 deg. C., implying that the temperature scale, which assigned 100 deg. C. to the difference between the melting-point of ice and the boiling-point of water, and which it was intended to carry on uniformly with equal increments of heat, was in error by that amount, at 450 deg. C. The cumulative effect of such an error in the doubtful work of extrapolation can be easily understood. In the measurement of the highest temperatures we are still liable to deviations from absolute uniformity, because we have no means of reference to the gas scale, nor can we be sure that we are dealing wholly with calorific radiation. But thirty years ago, the settlement of the boiling-point of sulphur was epoch-making and led to new standards of thermometric accuracy. Previous to the classical investigation of Callendar and Griffiths, the sources of error that effected the result were only imperfectly appreciated. To insert a thermometer into the vapour to be tested was thought by many to be all that was needed. The difficulty of maintaining an enclosure at a constant and uniform temperature, indispensable for thermometer comparisons, was lightly regarded. Errors, due to superheating of the vapour or to loss of heat by radiation and condensation, were not carefully eliminated. The practical outcome of that inquiry was the recognition of the value of the platinum thermometer as a self-consistent and trustworthy instrument, remarkably free from change of zero and from secular alteration of its coefficients. The employment of an effective resistance box brought about a new order of accuracy in subdividing the Centigrade degree, and proved that the sensitiveness of the thermometer might be indefinitely increased. We believe that Principal Griffiths has succeeded in demonstrating differences of temperature that did not exceed one-millionth of a degree.

The oldest form of graduated measurements is by the expansion of mercury in a capillary tube, and it is to be feared that our familiarity with this form of thermometer has tended to blind us to its many and patent defects, as generally used. With the demand for greater precision, the mercury in glass thermometer has been submitted to critical examination and the necessity for many corrections shows that the apparent simplicity—its great recommendation—has been gained at the expense of accuracy. Dr. Griffiths examines these sources of error very carefully, showing what has to be done in order to express the readings in terms of the normal gas scale. It may be pointed out, that where high temperature mercurial thermometers are used, the employment of a scale deduced by extrapolation of the 100 deg. C. between ice and steam would lead to very serious errors. In the case of barosilicate glass, the difference at 500 deg. C. between the two scales may amount to more than 25 deg. C. Of course, such errors are avoided in modern instruments by the adoption of appropriate methods of calibration, but constant watchfulness is needed to ensure that the strains set up in the glass by thermal hysteresis, and other causes, do not effect the position of the zero. When other contributing errors are taken into account and the necessary corrections applied, few will question the author's verdict, that "where extreme accuracy is required, the simplicity of the instrument is more apparent than real, and that a well-designed resistance thermometer outfit easily surpasses it in sensibility, besides being free from zero depression, which is the inherent failing of the mercury in glass thermometer."

As a means of measuring high, but still moderate, temperatures, the resistance thermometer and bridge has proved unequalled among pyrometer devices for precision and reliability. The work of Callendar and Griffiths, already mentioned, demonstrated that the variation of resistance of platinum with change of temperature can be used to derive an expression of parabolic form, that would give results directly comparable with those of the air thermometer. From zero to 600 deg. C., the agreement was sufficiently close to warrant a considerable extension, and indeed by a slight variation in the constant of the formula, the readings might be employed without sensible error at all temperatures to which the materials used in the construction of a platinum thermometer can be subjected without injury. At 1,100 deg. C., the deviations are still small, but the reservations already mentioned have to be borne in mind. At this limit, the freezing-point of gold forms a well-defined transition point, admirably adapted for calibration purposes, and this fiducial point had been fixed by Barus, using a platinum vs. platinum-rhodium couple, calibrated in terms of a gas thermometer, at 1,093 deg. C. Holborn and Wien, employing practically the same method obtained 1,072 deg. C., a discrepancy of no less than 21 deg. C., Heycock and Neville reducing their observations by the parabolic formula found 1,061·7 deg. C., considerably lower than either result, but this value has been confirmed by Day and

Sosman, who have fixed the point at 1,062·4 deg. C. From very low temperatures to this upper limit, we may feel assured that one uniform scale of measurement based on the international definition of the degree Centigrade has been carried throughout, a triumph of experimental skill. To measure differences of temperature of 0·01 deg. C. demands resistance measures accurate to 0·0001 ohm. Practically this minute subdivision is effected by obtaining an approximate balance by a set of coils and making the final adjustments by means of a bridge wire, or set of shunted coils. The introduction of any sensible error is not to be feared from this cause, but it would be out of place to attempt to enter into details, which are fully described in the work, by one who is intimately acquainted with the process. For industrial work such refinements must be dispensed with, and several plans are indicated for obtaining the necessary robustness of apparatus with the requisite sensitiveness of indication, the treatise being intended for use, both in the factory and laboratory.

The thermo-couple rivals the resistance thermometer in offering a convenient and sensitive electrical method of measurement. The scale, depending on the assumption that the thermo-electric electromotive force varies uniformly with increase of temperature, can be extended much in the same way as that of the platinum thermometer, but the necessary limitations must be correctly apprehended, since the employment of more refractory materials offers inducement to apply the method to ever-increasing temperatures. Platinum with platinum-rhodium has been generally adopted as the standard couple, being more permanent at high temperatures than some combinations which may prove more economical in working, but as these so-called "base metal" couples are largely used industrially, the author might have considered them a little more fully. The potentiometer method of measuring the E.M.F. is given in great detail, but the simpler, if less exact, plans adopted in furnace practice, by which the E.M.F. is measured directly by a galvanometer, receive little attention.

The problem of measuring high temperatures—a problem in which theoretical deduction aids mechanical ingenuity—gives rise to some very interesting chapters. Practically there is only one temperature phenomenon available for the purpose, the radiation from the black, or perfectly absorbing, body. With such a body, which can be more or less perfectly realised in practice, it can be assumed in conformity with the Stefan-Boltzmann law, that the energy of complete diffuse radiation is directly proportional to the fourth power of the absolute temperature. On this supposition, which says nothing of monochromatic radiation, the black body takes the place of a perfect gas in the definition of the gas scale. The author gives concisely the evidence on which depends the continuity of the international with the radiation scale, and the conclusion that there is no breach of continuity throughout the measured range of temperature will probably be accepted as valid. The importance of this decision cannot be overestimated, for it suggests a method of measuring the highest temperatures encountered. This method is realised in radiation pyrometers, since no part of the measuring apparatus is submitted to the temperature of the furnace. The indications of the pyrometer must, however, be accepted with caution. It may be questioned whether we have a temperature of 3,500 deg. C., that of the carbon arc, for example, in the same sense that we have a temperature of 600 deg. C. Extrapolation has not only been carried to an unwarrantable, or at least, an excessive length, but an entirely new temperature phenomenon has been linked up with the old one and the continuity asserted.

Convenience of measurement has, however, not stopped here. We have optical pyrometers, and their accuracy must depend on the construction placed on the distribution of energy in the spectrum. The Stefan-Boltzmann law, as already said, does not apply even approximately to monochromatic radiation, and we must further accept Wien's deduction that with increase of temperature, the wave length of every monochromatic radiation diminishes in such a way that the product of the wave length and temperature remains constant. The expression, well known as Wien's "displacement law," resting on arbitrary assumptions, however, is the most satisfactory of the equations proposed to represent the distribution of spectral energy in "black" radiation. In that part of the spectrum where the maximum intensity occurs, Wien's equation represents the distribution of the intensity quite satisfactorily. Among the longer waves of the infra red the formula fails, and this want of agreement throws some doubt on the completeness of the theory, and consequently on the adequacy of the formula. But convenience outweighs suspicion and the optical pyrometer flourishes, and thanks to the accurate methods of calibration now employed, this form can be regarded as a reliable scientific instrument.

The author does not enter minutely into the mechanical construction of pyrometers, that is not the object of the treatise, but he gives in quite sufficient detail the theory on which construction is based, and explains how accuracy, or at least identical, results are secured. He puts before us in a lucid and convincing manner a scheme of practical pyrometry, and by inference, we can see the extent to which the accurate methods employed in the National Physical Laboratory have contributed to the advance of the science of heat measurement. The illustrations are well chosen and well reproduced. An adequate bibliography accompanies each chapter, and we hope it may not be considered ungrateful if we say that the index might have been extended with advantage.

Electric Motors and Control Systems. By A. T. Dover. London: Sir Isaac Pitman and Sons, Limited. [Price 16s. net.]

The sub-title of this book is "A Treatise on Electric Traction Motors and their Control." In the preface it is stated that "this book is an amplification of a portion of the author's work on 'Electric Traction.' It treats of the principles and special features connected with the application of electric motors to electric tramways and railways. . . . The author has endeavoured to treat the subject in a manner which will meet the requirements of the engineer and the advanced engineering student rather than those of the specialist in electric railway equipment."

The book is divided into 10 chapters, of which the first deals generally with the selection of traction motors; the second, third and fourth with continuous current, single-phase, and polyphase traction motors respectively; and the fifth with the testing of traction motors. Chapters VI, VII, IX and X are devoted to the control of continuous current tramway motors and railway motors and single-phase and three-phase railway motors; while Chapter VIII is concerned with the calculation of resistances.

Chapter I is of a quite elementary nature. In it are derived expressions for the force necessary to accelerate a train, to accelerate the revolving parts of it and to accelerate it up a gradient. In this latter connection there is perhaps a danger that the author's meaning may be misinterpreted, since the reader may fail to note that the formula given shows the *additional* accelerating force required and not the total. This additional force is that needed to hold the train in equilibrium on the grade. Aspinall's formula for train resistance is quoted as standard for locomotive-hauled passenger trains and another formula, due to the author, and involving first and second powers of the velocity, is suggested for motor-coach trains. The chapter closes with a few examples. One of these refers to a train of 400 tons (total) running at 60 miles per hour; firstly on a level track and secondly up a gradient of 1 in 200, the resistance being taken at 15 lb. per ton. The outputs on the driving axles are given as 720 kw. and 1,260 kw. respectively. It is then stated that if the output during the ascent is limited to 746 kw. the speed will fall to approximately 42 miles per hour. This result is got by simply assuming that the specific train resistance will fall to 11 lb. per ton. Combining the data given with Aspinall's equation gives the resistance equal to 10 lb. per ton and the velocity 44 miles per hour.

Coming to continuous-current motors the author gives characteristic curves of series, shunt, and compound motors, and in a very clear manner he shows the superiority of the series motor over the others, when running in parallel; the motors being supposed to differ slightly in performance from specification, as they will do; and the driving wheels being somewhat unequal in size. The effects of pressure rises and of the interruption and restoration of the supply voltage on series and shunt motors is also considered though in a qualitative rather than a quantitative manner. Having pointed out the several advantages of the use of commutating poles for traction motors, reference is made to their mechanical feature (many excellent illustrations are given); these special features, as compared with stationary motors being due to the necessary compactness and robustness of the traction motor, the compactness calling for the use of forced ventilation.

On the subject of regenerative braking it is interesting to note that on the Chicago, Milwaukee and St. Paul Railway, on which the locomotives carry 1,500-volts series motors, each of 452 h.p., provision is made for this by over-exciting the fields by means of a separate exciter. Automatic control of the return current is said to be obtained by regulating the field of the exciter by a motor-driven field rheostat.

The theory of single-phase motors is treated solely by the vector method, which we think is somewhat of a mistake; as some points are more conveniently dealt with by the algebraic method, and we think it desirable that the student should be acquainted with both. Further, there is no attempt made to show that the vector method is applicable to the phenomena under discussion, and when it is considered that these phenomena include the rotation at any speed of an armature in a variable field (in time) we are entitled to inquire whether the induced voltages are of the same frequency as the applied voltage or not; since if they are not the vector diagram is impossible. In fact, too many points are assumed. For instance, in the first paragraph the author states that if a direct-current series motor with laminated fields is supplied with alternating current at low frequency, then, except for commutation, it will be found to possess operating characteristics similar to those of a direct-current series motor. Having stated this he uses some of these characteristics to develop a theory, whereas what one expects is the development of the theory from first principles and a demonstration of the characteristics from the theory. The discussion of commutation is extensive and very good. The treatment of the various types of repulsion motor is very much better than that of the series motor. Several good illustrations of commercial motors are given with performance curves and details of windings.

On the subject of polyphase motors a knowledge of general theory is assumed, and the bulk of the discussion is on windings suitable for pole changing for variable speeds (there being little to say about the cascade system of speed regulation). The winding diagrams and tables are numerous and clear. There is, among others, a very interesting illustration of a 1,300-h.p. motor with cranked rotor shaft, the slip-rings being outside the cranks.

In Chapter V the methods of testing continuous current motors is gone into in great detail. A diagram is given of a switchboard by which the necessary connections may be made and a method of reducing and tabulating the results of the tests is illustrated by example. We notice that with regard to the measurement of the core-loss: the author prefers to drive the motor as generator by means of a smaller shunt motor, the driven machine being separately excited, and measure the input to the driving motor; rather than to measure the input to the motor directly when running light and separately excited. His reason is that greater accuracy is obtained. In our opinion the reverse is the case. The testing of single-phase motors is not quite so fully treated, and nothing is said about three-phase motors, presumably because, as we believe, these have not come into use in this country for traction purposes. The method of making service tests is explained, and the chapter closes with a short description of the Wimperis accelerometer.

The descriptions of the methods of controlling continuous-current tramway and railway motors and of the apparatus used for that purpose are very excellent. Along with the developments of the controllers are given diagrams showing the relations of the motors to each other and the resistance steps, which will save the reader a vast amount of trouble in studying the subject. We think it would add to the value of the work if some more detailed drawings of contactors were introduced. For some reason the author refers to what has been generally called a controller drum as a cylinder or a spindle, which is not very helpful.

The calculation of starting resistances is explained in a manner that could hardly be improved upon. Both the algebraic and "curve" methods are worked out, with examples, and while both methods are rather tedious the author is generally in favour of the latter.

With regard to the control of single-phase motors which is clearly put forward, we think it would be well if a more detailed discussion of the induction regulator were given, though there are references to articles where fuller information is to be found. The same observation occurs to us on reading the chapter on the control of three-phase motors. It would appear that for main line electrification the system of single-phase generation and transmission to the locomotive, the conversion there of the single-phase to three-phase power by means of the induction regulator and the Scott transformation and the use of three-phase motors, involving as it would the employment of alternating current throughout without commutating apparatus—presents considerable advantages.

The remainder of the book includes an appendix giving the A.I.E.E. rules so far as they are relevant, a set of examples taken from recognised examining bodies, and a useful index.

In conclusion, though a few parts of the book suggest hastiness in writing, we can confidently recommend the work to all who wish to be fully conversant with the subject treated.

BOOKS RECEIVED.

United States Department of Labour. Bulletin of the United States Bureau of Labour Statistics. No. 209. *Hygiene of the Printing Trades.* By Alice Hamilton, M.A., M.D., and Charles H. Verrill. [Price 20 cents.] Bulletin No. 239. *Wages and Hours of Labour in Cotton Goods Manufacturing and Finishing.* [Price 20 cents.] Washington: Government Printing Office.

Department of Scientific and Industrial Research. First Report of the Mine Rescue Apparatus Research Committee. London: H.M. Stationery Office. [Price 1s. 9d. net.]

Memoirs of the Geological Survey, Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1917. London: E. Stanford, Limited. [Price 2s. net.]

Third Annual Report of the National Advisory Committee on Aeronautics, 1917. Washington: Government Printing Office.

Transactions of the Institution of Naval Architects. Vol. LX. Edited by R. W. Dana, O.B.E., M.A., Secretary of the Institution. London: Henry Sotheran and Co.

Anuario de Mineria, Metalurgica, Electricidad y demas Industrias España. Publicado por la *Revista Minera, Metalúrgica y de Ingenieria* bajo la dirección de Don Andriano Contreras y Don Romar Oriol. Año 1918. Madrid: "Grafica Excelsior," Campomanes, 6. [Price 7 pasetas.]

Modern Engineering Measuring Tools. By Ernest Pull, M.A.Mech.E. London: Crosby and Son.

Industrial Chemistry, including Electrolytic and Electro-thermal Processes. By Eric K. Rideal, M.A.(Cantab.), Ph.D., F.I.C. London: Baillière, Tindall and Cox.

The Meaning of Industrial Freedom. By G. D. H. Cole and W. Mellor. London: Geo. Allen and Unwin, Limited. [Price 1s. net.]

The New Teaching. By John Adams, M.A., B.Sc., LL.D. London: Hodder and Stoughton. [Price 10s. 6d. net.]

An Introductory Treatise on Dynamical Astronomy. By H. C. Plummer, M.A. Cambridge: University Press. [Price 18s. net.]

Alternating Current Electrical Engineering. By Philip Kemp, M.Sc.Tech.(Vict.). London: Macmillan and Co., Limited. [Price 17s. net.]

Works Lighting. By Daniel H. Ogley, B.Eng. London: Iliffe and Sons, Limited. [Price 7s. 6d. net.]

Power Plant, Installation, Upkeep and Economical Operation. By T. Roland Wollaston. Manchester: Sherratt and Hughes. [Price 5s. net.]

Russian Correspondence, Letters, Idioms, Grammatical Notes, and Full Vocabulary. By A. S. Mindel, B. Com. Manchester: The University Press; London: Longmans, Green and Co. [Price 3s. 6d. net.]

LIQUID CRYSTALS.

To the Editor of Engineering.

Sir,—The article on liquid crystals appearing on page 349 of your issue of September 27, is not only of scientific interest and value to those students who are especially associated with research laboratories but to many who, in the domain of metallurgical practice, are endeavouring to understand more clearly the *rationale* of crystallisation and grain growth.

We are indebted to Drs. Desch and Rosenhain for much light on these problems as bearing upon the crystallisation of iron and steel, but as yet the function of liquid crystals in the mechanism of freezing of ferrous alloys is little understood. The research is admittedly a difficult one, and there is little chance of being able actually to observe the marshalling of liquid crystals and their orientation in the possible phase lying between the structureless superheated liquid metal and the undercooled phase wherein the solid crystallites first grow.

Fig. 1. White Pig Iron; Quenched from Molten in Water. 200 Diameters. White Dendrites, Austenitic.

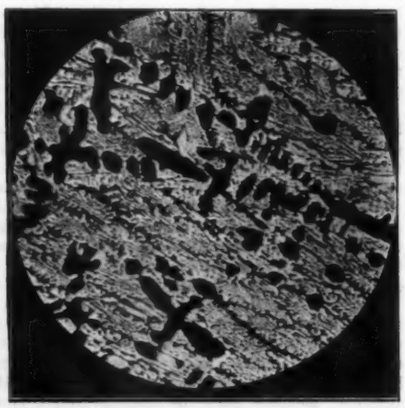


Fig. 2. White Pig Iron; Cooled from Molten Slowly. 68 Diameters. Dark Dendrites, Pearlite.

It is readily conceivable that there is such a phase, and that its position is immediately above the generally recognised liquidus curve of the Austen-Roozeboom equilibrium diagram of the carbon-iron alloys. In examining microscopically carbon-iron alloys superheated beyond their melting-points and quenched from the liquid state in water or freezing mixtures I have noticed that in hypo-eutectic alloys (containing from, say, 2 per cent. to 3 per cent. carbon) the eutectic plates generally run in parallel directions over considerable areas, traversing isolated iron crystallites or dendrites which were the first to freeze in the primary "eutectic-plus-iron" liquid. These eutectic plates grow at right angles or nearly so to the cooling surfaces of the frozen mass, and in growing inwards meet with iron dendrites already solid or quasi-solid. The curious fact is that though thus opposed by such solid crystals of iron the direction of the eutectic plates continues without deflection in many cases through the dendrites, appearing on the other side without change of orientation. In the words of your article "these liquid crystals may drift along a trough across which wires have been stretched and float right through the wires to close up again and to resume their original shape, &c.," the mysterious phenomenon may be possibly explained. The eutectic plates may first have been liquid crystals. They first grew under the conditions of falling temperature starting on their journey from the cooler outer envelope as liquid crystals, meeting the already frozen iron dendrites, passing by them and closing up again in their further advance towards the still structureless liquid mass centre. It has been proved that the phenomena observed by Lehmann does not merely apply to pure crystals, but to those which have been contaminated by gas or air bubbles and other impurities which "suspended in the liquid take up symmetrical positions in the crystals, or between them, as if they formed part of the crystal structure." Similarly in steels or cast irons the occlusion of gases in a fine state of division may actually be primarily connected with the liquid crystal formation, which may be specially encouraged in the case of metals containing eutectics or combinations leading later to eutectoid structures, when melted under conditions of high superheat (*i.e.*, heated to temperatures above their true melting-points). In steels and cast-irons "high-superheat" melting is associated with excessive gas and oxide occlusions, possible solution of ferrous oxide which at lowering of the temperature probably reacts with carbon and other metalloids present, and with coarse columnar crystalline structure radiating from the envelope of the ingot or casting as in the case of so-called "scorched" crucible steel ingots. In a word, the liquid crystal phase may have a very practical bearing on many melting problems which to-day are difficult to solve.

I am enclosing two microphotographs as illustrating the persistence of direction in the eutectic plate structure of a carbon-iron alloy containing about 3 per cent. carbon, after passing isolated iron dendrite.

Yours faithfully,
J. E. Fletcher.

Netherton Iron Works, Dudley,
September 28, 1918.

"TESTING AIR COMPRESSORS."

To the Editor of Engineering.

Sir,—Apparently your correspondent "Interested" is unwilling to admit that the results of a carefully-conducted test are of more value than figures based on assumptions, however plausible.

The evidence he puts forward in support of one of his assumptions is not very convincing. He can hardly expect me to agree that an indicator diagram taken at considerably below full speed which appears to support his views, is to be preferred to one taken under the normal full load conditions which corroborates mine. It was sufficient to modify only two of "Interested's" assumptions to show that almost any result could be obtained by making more or less plausible assumptions. I might have corrected the others and made my case still better, but I proved my point without them.

I have many friends among consulting engineers and others responsible for the installation and testing of air compressors, and the statement that they are people who know very little about air compressors is so wide of the truth as to be hardly worth contradicting. He will, I hope, pardon my bluntness, but I am indebted to such gentlemen for much useful information on the subject of compressed air, and particularly as to the accurate measurement of it. Of course, I agree that a test sheet showing obvious errors is of little value, but surely he does not suggest that manufacturers of repute make a practice of sending out inaccurate and misleading test sheets.

"Interested" and one or two others are so obviously out to disparage these tests that I am afraid it is only wasting time to say anything further. If this country is to hold its own in the world's markets after the war, we shall really have to pull together a bit more and not be so desperately anxious to belittle one another's achievements.

Yours truly,
John M. Walshe.

38, Constance-road, Edgbaston, Birmingham,
October 1, 1918.

"COAL SAVING BY SCIENTIFIC CONTROL OF STEAM BOILER PLANT."

To the Editor of Engineering.

Sir,—May I be permitted to reply to the criticism of your esteemed contributor and correspondent, Mr. D. Brownlie, contained in his letter which appeared on page 326 of your issue of September 20, as to the relative commercial value of coal and coke as fuel for steam raising. One result of the coal redistribution order is the deterioration in the quality of gas coke owing to gas supply authorities being obliged to accept, from strictly defined areas, coal which is often relatively dirty and unsuitable for carbonising. Shortage of labour at the pits has also contributed towards the increased ash content of gas coal. In spite of these facts and alleged excessive moisture, the average evaporation obtained per pound of coke *as fired* at various London factories, institutions, and at the works of the more important public utility authorities is about 9·8 lb. from and at 212 deg. F. The average obtained by Mr. Brownlie over long periods with provincial coke is 9·25 lb., but at 35*s.* per ton Mr. Brownlie states that coke is too expensive. In appraising the value of gas coke due allowance must be made for its valuable smokeless characteristic, as in the case of Welsh coal, the price of which, for this reason, is always in excess of its relative net evaporative value. Like all other native solid fuels, the quality of Welsh coal has deteriorated, but the present price delivered in London is quoted 50*s.* per ton, and the average evaporation obtained by one user is very considerably under 10 lb. As Mr. Brownlie has shown, the average evaporation obtained with bituminous

steam coal does not exceed 8 lb. The comparative fuel cost of evaporation with coal and coke at current rates in London is, therefore, approximately, as follows :—

	Cost per Ton.	Net Evaporative Value.	Fuel Cost of Evaporation per 1,000 Gallons from and at 212 Deg. F.
	s. d.	Lb.	*s. d.*
Welsh coal ...	50 0	10·0	22 4
Hard steam ...	40 0	8·0	22 3
Gas coke ...	41 8	9·8	19 0

Saving effected by using coke, 14·5 per cent.

The relative price of coal and coke varies, of course, according to local conditions ; and it may be argued that the average user cannot obtain the best results with coke because his furnace conditions are not quite suitable. But that is no reason why the inefficient steam user should be subsidised at the expense of the gas consumer, who must inevitably bear the loss due to any reduction in the price of coke. Boiler furnaces are usually readily adaptable to the use of coke, and the cost of adapting either mechanical stokers (chain grates) or hand-fired boilers is trivial compared with the saving to be effected.

In reply to Mr. J. H. Anderson, I can only say that the normal full-load steam consumption of the London Coke Committee's forced draught apparatus (3 per cent.) was determined by Mr. Brownlie ; and knowing as I do the painstaking thoroughness of his methods in conducting steam boiler and fuel efficiency tests, I have no reason to doubt the accuracy of this figure.

Yours faithfully,
E. W. L. Nicol,
(Engineer and Fuel Expert, London Coke Committee).

84, Horseferry-road, S.W. 1,
September 27, 1918.

THE WEIGHT OF AERO AND DIESEL ENGINES.

To the Editor of Engineering.

Sir,—In your leader of 20th ult., dealing with the weights of aero engines and Diesel engines respectively, it seems curious to the writer that no mention was made of dimensional considerations.

It is stated correctly that "With internal-combustion engines the larger the power per cylinder the higher the weight per unit of power developed," but the explanation "due primarily to heat stresses requiring a reduction in effective mean pressure developed within the working cylinder and to large increases in the thicknesses of metal to conduct away a sufficient percentage of the surplus heat of combustion" seems to me misleading.

The primary considerations are illustrated, I think, by the following example.

Consider any given aero engine weighing, say, 3 lb. per brake horse-power and also an exact model of this engine made to half the scale of the original. A little reflection will show that this model would possess the following properties :—

(1) It would weigh one-eighth of the original.

(2) It would have the same air speeds, bearing pressures, bearing speeds and stresses (including inertia stresses) if run at the same piston speed as the original (*i.e.*, at double the revolutions) and on the same pressure cycle.

(3) If it were worked on the same pressure cycle as the original it would develop one-quarter of the power of the original at the same piston speed.

(4) Its weight per brake horse-power under the conditions of (2) and (3) would be one-half that of the original ; that is, 1·5 lb. per brake horse-power.

Now an average submarine engine cylinder has a bore and stroke roughly three times that of an average aero engine cylinder, so the latter has a 3 : 1 advantage on dimensional considerations only.

Accepting the figure 10 given in your leader for the ratio of weight per brake horse-power of Diesel engine to weight per brake horse-power of aero engine, there remains a ratio of 3½ : 1 to be accounted for by the considerations enumerated in the article, viz. :—

(1) Reduced M.E.P. in large engines compared with smaller.

(2) Additional metal not required for strength but fulfilling the function of heat ducts.

(3) Use of cheaper metals of low strength value.

(4) Conventionally low piston speed.

There are other considerations, some of them ignored in recent papers on the subject, but their consideration would unduly lengthen this letter.

My only excuse for these comments is that the dimensional aspect of weight coefficients is frequently lost sight of, with the result that figures for different sizes of engines create quite a misleading impression as to the extent to which further reduction is possible.

Yours faithfully,
H. F. P. Purday.

7, Essex-road, Basingstoke.

[If all practical factors be neglected the weight of an engine may be said to vary as the cube of the linear dimensions, and as a check in estimating weights this rule is often used as a guide, the dimensions being the cylinder diameter squared multiplied by the stroke. If a constant piston speed be assumed, the power may be said to vary as the square of the diameter, so that, on this account, the larger the engine, the greater the weight per unit of power developed. On the other hand, practical considerations limit the minimum dimensions, more particularly thicknesses, for many of the parts of an engine, and low-powered engines tend on this account to come out relatively heavy, counteracting the law mentioned by our correspondent that the weight varies as the cube and the power as the square of the dimensions. Relatively constant weight per unit of power over a considerable range of size of engines of similar type is actually the case in practice.—Ed. E.]

THE STORAGE OF PETROLEUM.

To the Editor of Engineering.

Sir,—We read with much interest the article appearing in your September 20 issue under heading "The Storing of Petroleum." We notice that attention is drawn in this article to the possibility of extinguishing burning oil in a tank by "a blanket of foam," and we think it possible that the writer may have had in mind the system of oil fire extinguishing known as "Foamite," of which our friends MacAndrews and Forbes Company, of New York, are the proprietors. The author states : "If the fire is on the roof, smouldering embers will fall back into the tank causing re-ignition of the whole mass, though the fire along the surface of the oil way have been previously quenched" ; but with the "Foamite" system this risk is eliminated.

We have before us as we write an account of a fire which occurred at the Tank Farm of the Southern Pipe Line Company, Millway, Pennsylvania, in one of the 94-ft. diameter tanks having a capacity of 35,000 barrels, with a wooden roof of 1-in. boards. In this instance the roof fell in immediately, but held partly to the sides of the tank, making an inverted cone, the foam in the angular space surrounding this cone was not able to reach the oil burning it it, so that it was necessary to attach foam hose connections to the "Foamite" apparatus permanently fixed to the tank and to play into the centre of the tank. At about the same time the cone split allowing the foam in the angular space to reach the centre, 25 minutes from the time of ignition the oil fire was completely extinguished. The wooden portion of the roof remaining under the steel sheets of the roof continued to burn, but the oil being covered with foam did not re-ignite.

As the author states at the commencement of his article, provision of safety from ignition has been given a great deal of attention in the United States, and doubtless now that the storage of oil in Great Britain is being done on a large scale the experience gained in America will not be neglected by those interested in the oil trade in this country.

The method of isolating tanks with a view to protecting them from fire as described in the article is a good one, but you will doubtless agree that if a system of fire appliances can save the contents of even one tank it would be an improvement to the method of allowing the contents of such tank to burn out and the consequent wreckage of the tank itself. From the many reports we have received from America a very small quantity of oil need be lost and the tank itself saved if the "Foamite" apparatus is attached.

It may interest you to know that practically all large oil producers in America and Mexico have adopted the "Foamite" system, and that well over 6,000 tanks are protected by this method. The list of firms adopting same include such well-known names as—

The Standard Oil Company.
Gulf Refining Company.
Vacuum Oil Company.
Anglo-Mexican Petroleum Oil Company.

And among the big industrial concerns are—

The Bethlehem Steel Works.
Du Pont de Nemours Powder Company.

The United States Navy, with characteristic perspicacity, at once adopted the hand extinguishers on their oil-fuel vessels. Our own Admiralty have also evinced considerable interest in this system and preliminary tests are reported by them as satisfactory. If any of your readers wish to have further information and particulars about this system we shall be pleased to give them full details if they will write us.

We are, dear Sir, yours very truly,
MacAndrews and Forbes, Limited.
(D. Ashby Felton, Director.)

2, Broad-street Place, London, E.C. 2.
October 2, 1918.

PATENT LAW REFORM.

To the Editor of Engineering.

Sir,—On once more returning to this subject, might I ask your support in impressing upon the deputation which is to wait on the President of the Board of Trade almost directly, to make the following suggestions its principal text, when there is a possibility of some practical good being accomplished.

"We ought to have the same Patent Laws as America. We ought also to have an Empire Patent. With all the overseas representatives here, this could easily be arranged."—*Vide* Sir Robert Hadfield, Bart., in morning press, September 26, 1918.

In addition, a comprehensive and sound report by the Institution of Electrical Engineers has been accepted by the Conference as forming the basis for the criticism of the proposed two new Bills coming before Parliament. The report justly points out by inference that patents are granted to reward inventors, and that they should not be subject to conditions which simply amount to the legislation of robbery.

The requirement of compulsory working is, of course, not a modern requirement at all. I believe it is found in Letters Patent granted in the reign of Charles I, if not earlier. The philosophy of the subject is at least as old as the French Revolution, but surely by this time we ought to have got a long way from that ! The whole doctrine is, however, in my humble judgment, based on a fallacy.

It is enough to point out that when the Act of 1907 was passed, Mr. Lloyd George and others exulted over the circumstance that Germans were going to be compelled to put up factories in Great Britain. In actual fact, the Act did not have anything like the effect that it was alleged to have. The point is, however, that in so far as the Act may have led to the establishment of factories by Germans in this country, it simply led to the introduction of a number of very highly undesirable people. It will probably take us a long time to eliminate the undesirable element for which we have to thank the Act of 1907. Do we want to compel the Germans to come over here ? If we do, then let us have compulsory working, or, for that matter, compulsory immigration. If we do not want them, then for Heaven's sake don't invite them.

As regards the present obnoxious renewal fees, these ought in any case to be materially reduced ; but, beyond all that, there is no provision in the proposed Bill for the establishment of an official search through prior literature *other than British Patent Specifications*, which, of course, after all, leaves any so-called official search a mere farce.

What, I wonder, in all conscience, is the matter with the American patent system ? Under it, these objections are eliminated ; there are no renewal fees, no compulsory working, but no patent is granted unless it can stand a world's search ; in comparison, the existing American system *has stood the test of nearly a century, has encouraged invention, and has been eminently successful*, and possibly its only objection is that it is anything but German ! ! In the same period of time we in Britain have had numerous Patent Acts, mostly on German lines, and not one of them has been worth a cent so far as the encouragement of invention and progress is concerned, as the report of the Electrical Institution for the guidance of the deputation and the Board of Trade clearly shows.

I therefore continue to be in full agreement with Sir Robert Hadfield in advocating the adoption of similar patent laws as the United States under a British Empire patent system, and in abjuring anything approaching German lines or procedure.

Yours faithfully,
James Keith.

"Highlands," Vernon-road, Leigh-on-Sea,
September 27, 1918.

United States Magnesite.—The output of magnesite in the six months to June 30, 1918, was about 93,700 tons, according to Mr. R. W. Stone, of the United States Geological Survey. The California output enters in this total for 47,600 tons and the Washington output for 46,100 tons. The rate of output in California was about 50 per cent. less and the rate in Washington about 88 per cent. less than last year.

University of London, University College.—A course of six lectures on "The Scientific Problems of Radiotelegraphy" will be delivered by Professor J. A. Fleming, M.A., D.Sc., F.R.S., University Professor of Electrical Engineering, on Wednesdays at 5 p.m., beginning October 30, 1918. The course is open both to members and non-members of the University. Fee, 1*l.* 11*s.* 6*d.* Application for tickets of admission should be made to Mr. Walter W. Seton, M.A., D.Lit., University College, London (Gower-street, W.C. 1).

Merchant Shipbuilding Output, September, 1918.—The tonnage of merchant vessels completed in United Kingdom yards and entered for service during September, 1918, compared with preceding periods, is given below :—

Month.	Gross. Tons. 1917.	Gross. Tons. 1918.
January	48,089	58,568
February	79,451	100,038
March	118,699	161,674
April	69,711	111,533
May	69,773	197,274
June	109,847	134,159
July	83,073	141,948
August	102,060	124,675
September	63,150	144,772
Total, nine months to September 30 ...	743,853	1,174,641
Total, twelve months to September 30 ...	957,185	1,594,262

An Exhibition of "Key" Industries.—Mr. H. J. Mackinder, M.P., chairman of the Tariff Reform League, desires to draw attention to the fact that, by permission of the Ministry of Munitions, an Exhibition of new British and "Key" Industries, organised by the Industrial Section of the League, will be held at the Central Hall, Westminster, London. The exhibition will be opened, by ticket only, on Monday next, the 7th inst., and to the general public, admission free, on and after Tuesday, the 8th inst. It will remain open until the 22nd inst., after which it will be shown in Manchester and other leading provincial centres of population. The object of the exhibition is to illustrate the facts respecting the more important of the so-called "key" or "pivotal" industries recommended for special treatment by the Government Committee on Industrial and Commercial Policy after the war.

THE LATE DR. HENRY DYER.

We regret to have to record the death, which occurred on Wednesday, September 25, of Mr. Henry Dyer, C.E., LL.D., chairman of the Glasgow School Board, and a well-known engineer.

Dr. Dyer was born at Bothwell, in 1848, and received his education at Wilson's Endowed School, Stane, Notts, at Anderson's College, Glasgow, and at the University. He served an apprenticeship to the engineering trade under Mr. A. C. Kirk, LL.D., and entered the University when he was twenty years of age, where he graduated M.A. and B.Sc. in 1873. In 1890, he took the degree of D.Sc. Towards the close of his university course, in 1872, Dr. Dyer received through Professor Macquorn Rankine, Professor of Engineering at the University, and Mr. H. M. Mathieson, the agent in London of the Japanese Government, an offer of the position of principal of an engineering college it was proposed to found at Tokio. He had made a special study of the methods of imparting instruction in engineering pursued in the chief centres in this country and abroad, and he accepted the appointment. In this position, Dr. Dyer did excellent educational work for Japan, many of his students now filling important positions in the industrial undertakings of the country. He remained ten years in Japan, during which time the college was firmly established. As marks of appreciation of his services, Dr. Dyer received from the Emperor the Order of the Rising Sun (Third Class), and the Government conferred upon him the title of Honorary Principal of the college; a few years later the Emperor conferred upon Dr. Dyer the Second Class of the Order of the Sacred Treasure. He was also one of the three foreigners whose name was placed on the roll of the Engineering College and in the chronology of the Imperial Ministry, at Tokio, an honour all the greater since it is not the custom in Japan to refer to individuals in Government records.

Dr. Dyer established later a consulting engineer's practice in Glasgow, and was frequently called upon to arbitrate in disputes between firms engaged in the manufactured steel trade and their employees. On the establishment of the Board of Conciliation and Arbitration of the Manufactured Steel Trades of the West of Scotland, he was appointed deputy-chairman. Through his intimate knowledge of the trade, and his strict impartiality Dr. Dyer enjoyed in an exceptional degree the confidence of both masters and men. He took a deep interest in education, especially from its technical side, and with ample leisure at command he was able in this important matter to render valuable services to the community. Soon after his return from Japan he was appointed one of the trustees of the Young Chair of Technical Chemistry in Anderson's College; and when that Institution was merged in the Glasgow and West of Scotland Technical College in 1886, under the Educational Endowments Act, he became a life Governor of the Technical College. He was also a Governor of Glasgow and West of Scotland Agricultural College. For a long period Dr. Dyer served on the Glasgow School Board, of which since 1914 he was chairman. To the general work of the board he gave unremitting attention; and he specially devoted himself to the development of the continuation classes.

Dr. Dyer was a voluminous writer. His published works include "Dai Nippon: the Britain of the East," an authoritative work on the rise and progress of Japan; "The Evolution of History," "Science Teaching in Schools," and "Education and National Life." For a considerable time Dr. Dyer had been engaged on a work dealing with industrial reconstruction and education. He also contributed to periodical literature numerous articles on educational, literary and social subjects. The honorary degree of LL.D. was conferred upon him by Glasgow University in 1910, and five years later he received the degree of Doctor of Engineering from Japan.

The Industrial Reconstruction Council.—A conference on Interim Industrial Reconstruction Committees will be held under the auspices of the Industrial Reconstruction Council on Tuesday, the 8th inst., at 6 p.m., in the hall of the Institute of Journalists, 2 and 4, Tudor-street, E.C. 4. The subject will be introduced by Mr. W. Henderson Fringle, of the Ministry of Reconstruction, after which the discussion will be open. No tickets are necessary.

Tri-Lingual Artillery Dictionary.—We have received from Messrs. Charles Griffin and Co., Limited, the English–French–Italian section of a Tri-Lingual Artillery Dictionary which they have now published. It measures 4¼ in. by 3½ in., and contains 92 pages of artillery technical terms in the three languages. The work has been prepared by Mr. Edward S. Hodgson for the artillery officers of the Allies and others immediately concerned with this branch of the Service, by whom it will be found useful. Each section is sold separately at the price of 5s. net, postage extra.

THE GERMAN IRON INDUSTRY.

A report from the Rhenish-Westphalian district states, that both the production and the sale of iron still show the stimulus of the war, although the requirements of different war departments are less urgent than some time ago. The general open market has been somewhat assisted in consequence, and more iron has been available for peace purposes. At the same time the military authorities maintain their control over the entire steel industry and do only relieve any steel or iron on the production of urgency certificates. The production in every respect shows an improvement over the winter production. This more especially applies to pig-iron, due to larger supplies of coke for the south-west German iron works. The works are also well provided for the winter, having secured fair stocks of coke. The usual shortage of rolling-stock in the autumn has already set in, and naturally affects mostly the more distant and out-of-the-way industrial districts.

The production of steel has so far been kept at a satisfactory level, and the increased use of scrap favours the Siemens-Martin steel process, which in output now equals that of Thomas steel, whilst in times of peace the proportion was about 2 to 3. The supply of scrap, however, is decreasing, and the same will be the case with the production of Siemens-Martin steel. The export to the East, Ukraine and Roumania, will therefore be limited, as the supply of certain classes of goods is impeded by an insufficiency of hard steel material. Some works have also received orders from former Russian customers, but the unstable state of affairs interferes with business in that direction, and works have still to rely upon work for the war departments. In industrial circles all are, however, agreed that they have enough of existing organisations, and that a further extension of them by no means is desirable. Instead of schedules and restrictions and coercion it is most urgent that the doors should be thrown wide open for the free development of the industrial forces, in every direction.

The question of raising the prices of iron products has again come to the fore owing to the higher prices for fuel which came into operation on September 1. The prices now in force were fixed more than a year ago, and were established as maximum prices from January 1, 1918, and were again confirmed on May 1. In spite of this, the works have repeatedly endeavoured to obtain a rise, but so far all these efforts have been in vain. An increase is more especially called for in the matter of iron ore, half-finished products and wire, but on the other hand there are articles, for which the current prices may still be considered fairly satisfactory. In the fixing of new prices the expected pig-iron tax of 5 marks to 10 marks per ton must, of course, be taken into consideration.

As far as the supply of raw materials is concerned, the iron industry appears so far to have overcome all difficulties. During the whole of the war there has never been any shortage of phosphoric iron ore, and the production of Thomas iron and Thomas steel has therefore all along been adequate and has not fallen short of the peace production. Of ore containing manganese the supply has been maintained during the war, although there has been some difficulty as regards ore with a high percentage of manganese. By reopening some old deposits in Siegerland, in the Lahn district, and in Upper Silesia, matters have been kept going, although the production has had to be kept within certain limits. So far the production of quality pig-iron has sufficed for the requirements of the military authorities, but there is no material available for other purposes any longer. Of Luxemburg pig-iron there has always been enough to satisfy the home market, and small quantities could now and again be spared for abroad. During the last few weeks the Pig-Iron Union has been able to supply the consumers a little more liberally, owing to the increased production. Attempts are again being made to supply the foundries with some stocks for the winter. At the rolling mills, railway material is at present particularly to the fore. Owing to the large current contracts with the Prussian Hessian State Railways, all other orders in this branch have to be held over. After lengthy negotiations the railway department has consented to a slight, but inadequate, rise in the prices, the cost of production having increased very materially. As regards field railways, matters are somewhat easier, part of the material of the *etappe* railways having been placed at their disposal. Girders and shaped irons are at present of less importance, their production being dependent on the requirements of the military authorities, and there is no production for private purposes. The supply of bar iron is also extremely limited, as only small quantities are given free. Permits are certainly granted for completion of stocks, but no works effect deliveries unless exceptional conditions prevail. Attempts which are now and again being made already now to place orders for the time after the war naturally have been entirely futile, no works under the present unsettled conditions entertaining them. For hoop iron there are already inquiries from the East from Finland and Ukraine; but the works do not appear to take much interest in orders from those quarters. Heavy plates remain fairly plentiful, but the production of thin plates is altogether inadequate, and there is a wide gap between supply and demand. Wire products are comparatively quiet, and the reduction in output refers more especially to barbed wire, the military authorities having materially reduced their orders. Rolled wire, however, meets with a brisk sale. The military authorities also continue to draw considerable quantities of wire netting, wire nails, &c. The demand for wrought tubes continues lively from locomotive and boiler makers, as well as the shipyards. Substantial quantities of well tubes go to Roumania. Steel tubes are also used for gas bottles and hand mines, and tube works continue fully employed, and will remain so for some time to come.

The Government continues to exert a serious pressure upon the iron and steel industry in connection with the prolongation of the Steel Union. The demand has been made in a somewhat urgent manner, that the large iron works must now decide upon a fundamental system for the future Steel Union, or the interference of the Government may be looked for, as in the matter of the coal syndicate. How the new rules are to be formed does not appear to interest them particularly, only the Government wants one or more unions to be promptly formed and of several years' duration. It is, however, a question, whether matters will move quite so quickly, as the authorities seem to think possible, for the obstacles in the way of forming a large, comprehensive union are rather increasing than otherwise. The different conditions under which the various concerns work and the uncertainty as to how the market will frame after the conclusion of peace, more especially in connection with the export constitute questions which make the matter far more complicated than what was the case with the coal syndicate. It must also be remembered, that the Steel Union is not popular amongst its members, that its influence dwindles from year to year, and that attempts at a satisfactory solution have been going on for a decade or so without leading to any such definite result as the Government now tries to enforce by a mere decree. The most likely outcome appears to be a temporary union for, say, twelve months.

Engineering Investigation in Brazil.—The Government, through the Department of Overseas Trade, are embarking upon another investigation abroad, this time they have agreed to share the cost with the British Engineers' Association of an investigation into the prospects for the engineering industry in Brazil. The investigator, whose name will be announced very shortly will spend probably twelve months in Brazil, and his reports will cover the whole field open to engineering enterprise. In carrying out this investigation we understand that the council of the association is not animated by any hostility towards the merchants and other existing channels through which engineering business has been carried on. They are desirous solely of obtaining for their members information of the requirements of the Brazilian market, the openings for engineering plant and machinery and particulars of the methods of doing business most likely to suit possible purchasers and users. It will be open to members who receive these reports to do business in any way they like. Some members of the association are already established in Brazil with branch houses, others already do business through the merchanting and importing houses. Therefore one result of this investigation should be to make manufacturers more willing to adapt their products and methods to local interests and in this way this investigation should make it easier for merchants to supply their Brazilian demands from British sources. The address of the association is 32, Victoria-street, S.W. 1.

Potash from Blast-Furnace Dust.—To cope with the potash position, says *The Board of Trade Journal*, a new branch of the Ministry of Munitions was formed in June, 1917, the Potash Production Branch, with Mr. A. S. Eaglemont, C.B.E., as Controller. The branch had a great asset in the fact that it could commence work armed with the results of some very valuable experiments carried out by Mr. Kenneth M. Chance, a director of the British Cyanides Company, Limited, and Mr. Lennox Leigh, of the North Lincolnshire Iron Company, on the production of potash as a by-product in blast-furnace working. In the autumn of 1914 an advertisement was inserted in the technical press by the North Lincolnshire Iron Company, offering for sale the dust collected by their newly-installed gas cleaning plant from their blast furnace gases. This advertisement attracted the notice of the British Cyanides Company, who made arrangements with the North Lincolnshire Company, by which a joint investigation upon the possibilities of working up the blast furnace dust available into commercial products was to be conducted. In April, 1915, the first investigations were made, but owing to alterations in the plant that were soon found necessary, it was not until early in 1916 that direct experiments could be begun. After a long period of painstaking and scientific work, Mr. Chance developed his idea that the addition of a small proportion of common salt (chloride of sodium) to the charge of the furnace would release the potash present in the ore and cause it to be volatilised with the emerging gases as potassium chloride. Large scale tests, conducted during a considerable period, led to the conclusion that this process was not only successful in releasing very much larger quantities of potash in the dust, but also that it was in no way deleterious either to the quality of the pig-iron produced or to the lining of the furnaces. As a result of these experiments, it was estimated that it would be possible to recover by suitable means a maximum of 50,000 tons of potash salts per annum from blast-furnace dust alone; enough practically to meet the needs of the country. The great advantage of this dust as a raw material for potash supplies lies in the fact that the cost of its recovery may be regarded as negligible; clean gas, the main product of the necessary installation, is in itself valuable, and the cost of removing the impurities is therefore chargeable to the gas. The chief item of cost entirely chargeable to the potash is the value of the small amount of common salt added to the furnace burden, and even at the present price of salt this is not a great amount, owing to the small quantity necessary.

STEAM HYDRAULIC PLATE SHEARS.

CONSTRUCTED BY MESSRS. DUNCAN STEWART AND CO., LTD., ENGINEERS, GLASGOW.

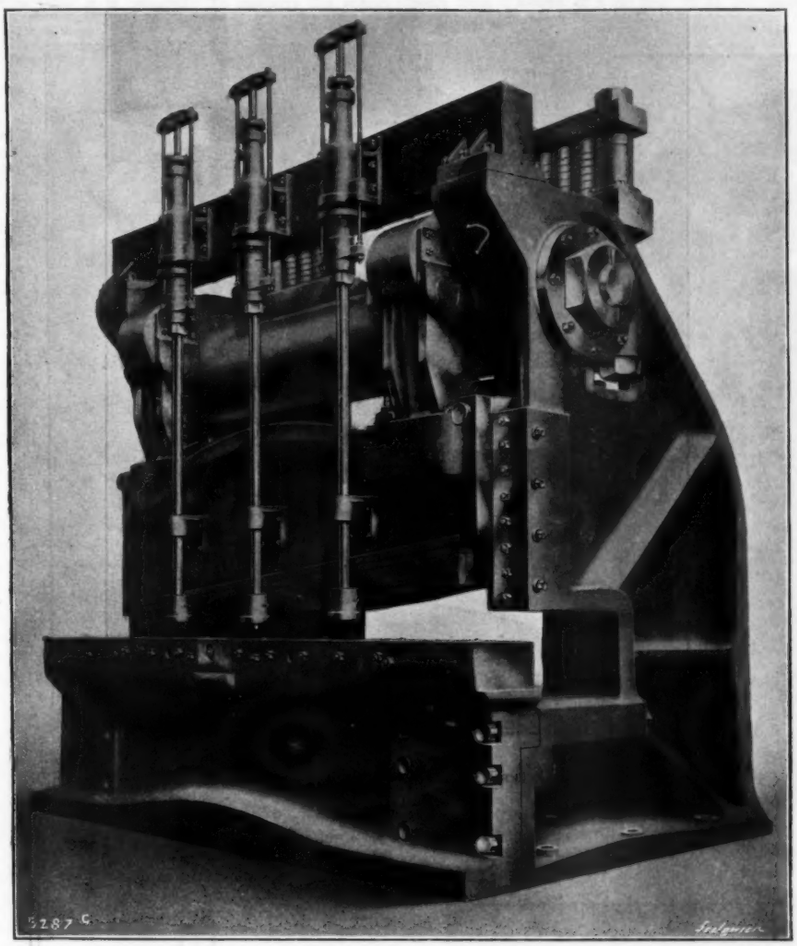


FIG. 13

We illustrate on this page and on Plate XXX, a set of steam hydraulic plate shears, one of which has been made by Messrs. Duncan Stewart and Co., Limited, London Road Iron Works, Glasgow, and two more are in the course of manufacture. These are for cold shearing steel plates of a tensile strength of 40 tons per square inch. Two of the sets are for cutting plates up to 1¼ in. thick, 8 ft. long at one stroke, and the other for plates 1¼ in. thick, 11 ft. long. The shears are very quick in action and will make 20 cutting strokes per minute when cutting plates two thirds of the maximum thickness.

The illustrations, being in detail, give a good idea of the design, size, strength and compactness of the plant, while the sectional drawing of the plant enable the handing and operation of the machine to be understood. A perspective view of the shears is given on this page. On the two page plate, Figs. 2 and 3 show the general arrangement, Figs. 4 and 5 details of the intensifier, and Figs. 6 to 12 show fully the shears. It is not therefore necessary to enter upon a full description.

The steam hydraulic intensifier (Figs. 4 and 5) is of the inverted type fitted with the rapid action automatic controlling and safety gears, which, in addition to cutting off automatically the steam to the intensifier at a point corresponding to the position of the handing lever, also prevents the handing lever from being moved further in the steaming direction than is necessary to steam the intensifier at the particular position the piston occupies in the cylinder. The shears (Figs. 6 to 12) have a gap of 36 in. enabling 6 ft. wide plates to be split down the middle. The side frames are massive steel castings tied together at the top by a large diameter forged steel shaft on which the cast steel rocking levers oscillate. They are further tied together at the bottom by the cast iron knife holder, and a heavy cast iron box section girder bolted in between the standards. The hydraulic cylinders are of cast steel, the rams are of chilled iron, ground on the working surfaces. Ball bearings are fitted in the top surfaces of the bolster to facilitate the easy manipulation of the plates. To the shears are fitted three cramping rams to hold the plates in position during cutting.

In addition to these shears, Messrs. Duncan Stewart and Co., Limited, have in hand a large number of forged presses, slab shears, billet shears and rolling mills to the designs of Mr. T. E. Holmes (late of Messrs. Davy Brothers, Sheffield) who has joined this firm. To enable them to meet increasing demands they have nearing completion a large and well equipped engineering works.

MALAY TIN DEPOSITS.—In his annual report for 1917 Sir E. L. Brockman writes as follows, says *The London and China Telegraph*: Leaving out of the question the paramount necessity of producing as much tin as is required for war purposes, the question of the future of the tin industry in the Federated Malay States is one which deserves grave consideration. The tin deposits of the Federated Malay States are not inexhaustible, but they have been, and are being, drawn upon at a very rapid rate, and those who are responsible for the administration will after the war have seriously to consider whether they will best serve the interests of this country and of the British Empire, and, indeed, of the world generally, by encouraging the more rapid exhaustion of the tin deposits, or whether it will not be more prudent to adopt a policy which will tend to conserve rather than promote the waste of this valuable metal.

SOME USEFUL TESTING MACHINES.*

(*Concluded from page* 356.)

Hardness Testing Machines.—The various forms of impact and pressure machines for determining the several values of hardness of metals are now well known, and serve the useful purpose of being able to connect by a simple factor the hardness value with a close approximation to the tensile strength of the material. Table III gives a useful list of equations connecting the tensile strength in tons per square inch of various steels, both alloy and plain carbon, with their hardness on the Brinell and the Shore scleroscope scales, as also the relation which exists between these two scales for the steels concerned.

TABLE III.—*Equations connecting the Tensile Strength in Tons per Square Inch with the Hardness of various Steels on the Brinell and Scleroscope Scales, also the two Scales with one another.*

Steel.	T.S. from Brinell No. "B."	T.S. from Scleroscope, Value, "S."	Brinell No. from Scleroscope.
Carbon	0·325B—12·5	1·96S—12·5	5·6S+0·14
Nickel	0·318B—14·3	1·56S— 2·7	5·0S+0·48
Chrome-Vanadium	0·318B—12·9	1·87S— 9·4	5·5S+0·27
Low Chrome Nickel	0·304B— 9·8	1·65S— 0·45	5·4S+0·33
High chrome nickel	0·318B—14·7	1·65S— 1·34	4·8S+0·58
Average ..	0·312B—11·6	1·80S— 6·7	5·5S+0·28

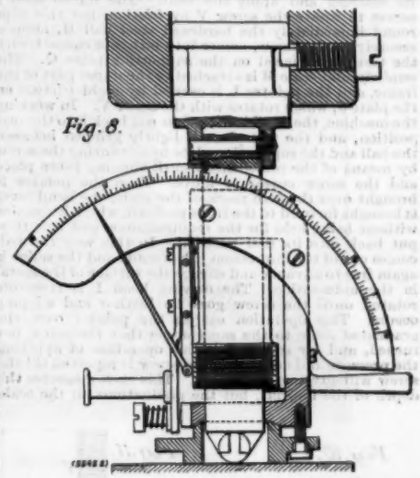


Fig. 8.

One method of performing the Brinell test is by the insertion of a special carrier in the crown of the Amsler testing machine and bringing up the pressure to the required amount on the test-piece, measuring its value on the dial scale (Fig. 8). The diameter of the impression may be read with sufficient accuracy by means of a transparent taper scale, and the corresponding hardness value in kilogrammes per square millimetre may be derived from a graph made on logarithmically-squared paper to save the use of long tables of figures.

Instead of the diameter, the size of which is sometimes doubtful in the case of soft metals, it is often preferable to measure the depth of the Brinell ball imprint to get the area of the cavity in terms of the product $\pi D t$, where D is the ball diameter and t the impression depth, both in millimetres. Messrs. Amsler Brothers have a very neat form of depth indicator which may be inserted in their compression machine in the same way as the ordinary bolster carrying the plain ball. In this case the ball is held in a somewhat longer chuck, which passes through the body of the depth-measuring instrument made of bronze and provided with a collar carrying a very fine screw thread on the outside, and engaging the ball chuck by friction. The outer body of the instrument bearing the scale graduated in twentieths of a millimetre supports a ball-and-socket ring loosely held by three screws, and any motion of the ball chuck relative to the frame pushes open a retaining spring, lowers the finely-threaded screw collar, and rotates a pointer over the graduated scale. The method of operation is exceedingly simple, and the zero adjustment can be quickly and accurately performed. The smooth metal surface of the specimen to be tested is raised by the support in the cradle until it engages the 10 mm. steel ball, then the body of the instrument is slipped down on the chuck till the ring rests on the test-piece. By pulling out the disengaging handle to the left, the pointer swings loose, and can be brought near to the zero mark before again engaging the screw. If the pointer still misses the zero mark, the milled head of the screw can be rotated slightly to make the coincidence exact. The desired load is next

* Abstract of paper read by Mr. H. S. Primrose, M.I.M. metallurgist, Messrs. Crittall Manufacturing Company, Limited, Braintree, and Mr. J. S. Glen Primrose, A.R.T.C., metallurgist, Messrs. Ransomes and Rapier, Limited, Ipswich (members of the American Society for Testing Materials), before the West of Scotland Iron and Steel Institute, February 15, 1918.

applied, and the ball, entering the metal under pressure, carries the pointer over the scale to a point indicating the depth of penetration. Elastic deformation must be allowed for by releasing the load to all but about 20 lb., and then reading the correct depth. The construction of this compact instrument is shown in the diagram, Fig. 8.

A more recent form of the same type of depth indicator made by the firm of Amsler Brothers is shown in Fig. 9, which illustrates the application of the same principle in the determination of hardness by means of the 90 deg. angle Ludwik cone. The knurled ring surrounding the cone rests with it at the same level on the smooth surface of the test specimen. When the cone, under pressure, enters the metal the knurled ring remains on the surface and pushes back the outer frame of the instrument and thus rotates the pointer over the scale, each division of which represents a depth of penetration of one-hundredth of a millimetre.

Guillery Hardness Testing Machines.—A very useful form of portable hardness-testing machine, the results from which can be arrived at without any measurement or calculation, is that designed by R. Guillery and made by Messrs. Malicet and Blin, of Aubervilliers, France. The simplicity of construction is readily seen from the illustrations of the machine given in Figs. 10 and 11. The iron frame A contains in its lower part a powerful spring R which is made up of a number of discs forming a Belville spring. This is accurately standardised to give a pressure of 3,000 kg. to a plate Q carried on the central rod B passing through the spring, and this rod rests on the knife edge C. The forward movement of the hand lever G causes the cam to raise the bent lever D about its fulcrum and apply the load. The milled head I serves to rotate the screw V by friction, but this slips round immediately the hardened steel ball H, clipped securely to the screw, comes into intimate contact with the test-piece placed on the supporting plate Q. The semi-circular scale M is attached to the upper part of the frame, and the pointer L is carried by slight friction on the plate J, which rotates with the screw V. In working the machine, the hand lever is first put back into the rear position, and the test-piece is lightly gripped between the ball and the supporting plate by advancing the screw by means of the milled head until slipping takes place and the screw ceases to move. Then the pointer is brought over the zero mark of the scale, the hand lever is brought forward to the front position, where it remains without being held for the required time, and it is then put back into its first position. In this way the ball comes out of the impression it has made and the screw is again free to advance and engage the surface of the metal in the indentation. The driving head I is therefore rotated until the screw goes no further and slipping occurs. This operation carries the pointer over the graduated scale to the same angle that the screw has turned, and for soft metals this operation of applying the pressure and advancing the screw is repeated till the screw will advance no further. This then measures the depth of the imprint, but the graduations on the scale are so arranged that it is not the actual depth which it indicated, but the corresponding Brinell hardness number. The sole precaution needed is to ensure that intimate metallic contact exists between the ball and the test-piece, since any scale will spoil the correctness of the reading, which is ordinarily quite sufficiently accurate for commercial purposes. The hardness value can always be checked by measuring the diameter of the imprint in the usual way. A large size of this type of hardness tester has recently been brought out by Guillery, but as it works in the horizontal direction it readily enables the largest shells to be tested for hardness in any side position across a diameter. A sectional view of this machine is given in Fig. 12.

Impact-Testing Machines.—The importance of the impact test is gradually coming to be more widely recognised, and a valuable impulse to its adoption has been given by the latest results of the Committee of the International Association for Testing Materials, which were published recently by Charpy. He tested several different types of machine, which although working on such different principles as the drop-weight, the swinging pendulum, and the rotating flywheel, yet were found to give strictly comparable results, and these were found to be quite independent of the weight and speed of the tup used, and also of the weight of anvil used, provided, of course, that the steel used is thoroughly normalised, and that the method of holding the test specimen was not objectionable, but merely resting in its place.

The swinging pendulum type approved by the International Association is well known, but the Amsler vertical drop-weight machine mentioned by Charpy is less well known, and has recently been superseded by a new form of swinging hammer. This is shown in side view in Fig. 13, and consists of a heavy cast-iron base to which are bolted two upright channels supporting the pendulum and the elevating winch which can raise the pendulum either to left or right, depending upon how the detachable hook is attached. On falling from the left side the weight breaks the test-piece transversely and when falling from the right, tensile impact tests are made. A friction clutch holds the swinging arm in any desired position as the windlass raises the bob weight, and the operating handle cannot be moved by the weight

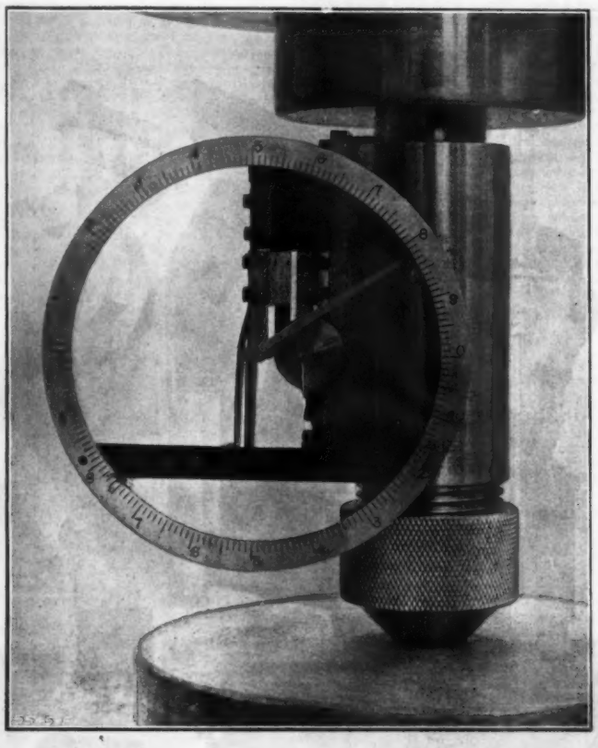
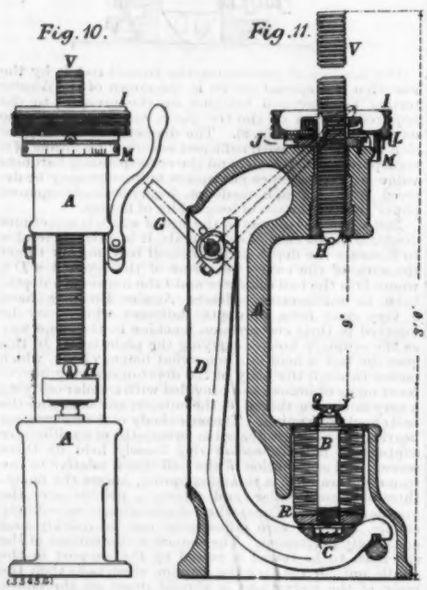
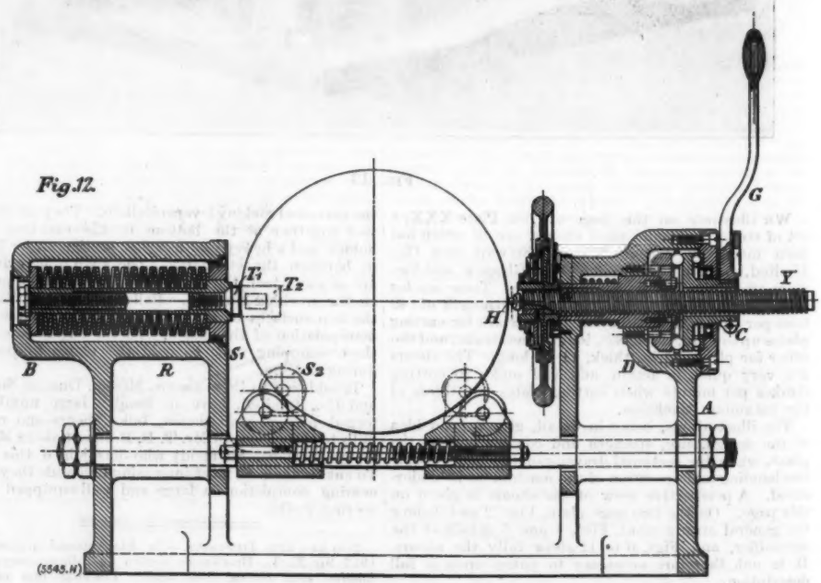


Fig. 9. Machine for Determining Hardness by 90-Deg. Angle Ludwik Cone.





Figs. 10 to 12. Guillery Hardness Testing Machines.

itself, but only by the operator. On pulling the release cord, the hook is detached and the tup falls freely, and after breaking the bar it swings up on the other side of the machine. Instead of swinging back, however, it is held in its position of maximum height by a third cord passing round a drum and acting as a brake. The circular weight at the end of this cord exerts a sufficient pull to prevent the pendulum from falling back from any position until it is released. To measure the energy absorbed by a blow of the pendulum the difference is noted between the readings of two scales provided on the vertical supports. The elevation of the weight moves a pointer over the first scale to show the energy stored before the blow, and the swing of the pendulum carries another pointer over a second scale to indicate the residual amount of energy after the blow. The change over from transverse impact to tensile impact test is readily accomplished by unhooking the elevating cord from one side of the tup and fixing it to the other side, then the windlass is wound up by turning the handle in the opposite direction from before.

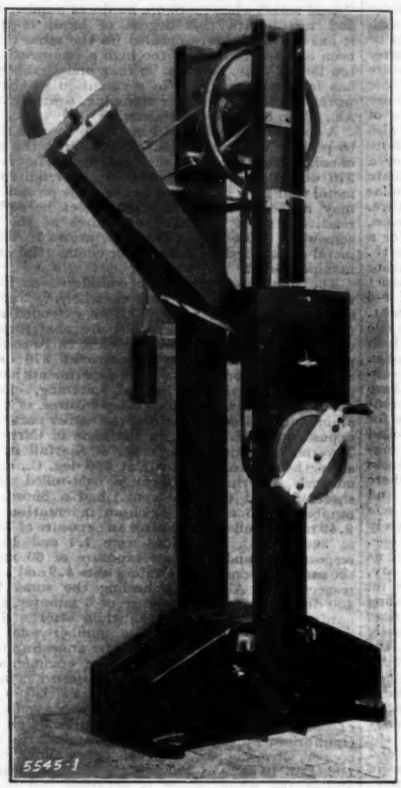
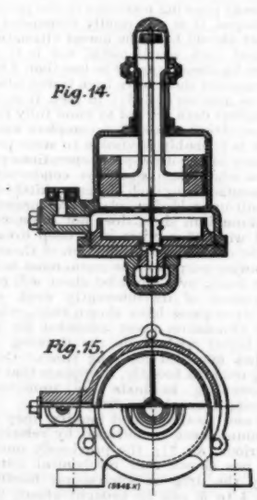


FIG. 13. AMSLER SWINGING-HAMMER TESTING MACHINE.



FIGS. 14 AND 15. PUMP FOR GUILLERY MACHINE.

Guillery Impact-Testing Machines.—The most convenient type of impact tester for works practice which entails the minimum of effort and calculation, is the rotary dynamometer tup or rotating flywheel made by Maiset and Blin to the design of M. Guillery. The latest form of this machine consists of a flywheel of such shape and size that when rotating at 302 r.p.m. the velocity of the striking knife is the same as that of a body falling freely from a height of 4 m. (say 29 ft. per second). The moment of inertia of the wheel is such that when running at this speed, the energy stored in it is 60 m.-kg. for the one size, and 275 m.-kg. for the heavier type of wheel, approximately 440 ft.-lb. and 2,000 ft.-lb. respectively. The lighter machine may be compared to a falling tup or "monkey" of 15 kg. weight falling from various heights up to 4 m., and these are registered by one of the speedometer scales. It is usual to work up to the highest reading and capacity of the machine, and for this reason the scale for measuring the energy absorbed in the blow has its zero at the top of the tube. The flywheel of the machine is made to rotate by a handle connected with an adjacent lever which, according to its position either puts the handle into gear for speeding up, or disengages to allow the wheel to run free. A third position applies a brake to stop the rotation of the wheel when the tests are completed. The connection between handle and wheel can be made readily when the wheel is in motion. An ingenious device throws the handle out of gear if it is attempted to turn the wheel in the wrong direction. The equivalent height of drop and the energy absorbed by the impact are read on the tachometer tube, the scale of which gives the highest reading when the wheel is at rest and adjusted to coincide with the 60 m.-kg. mark by means of a milled screw.

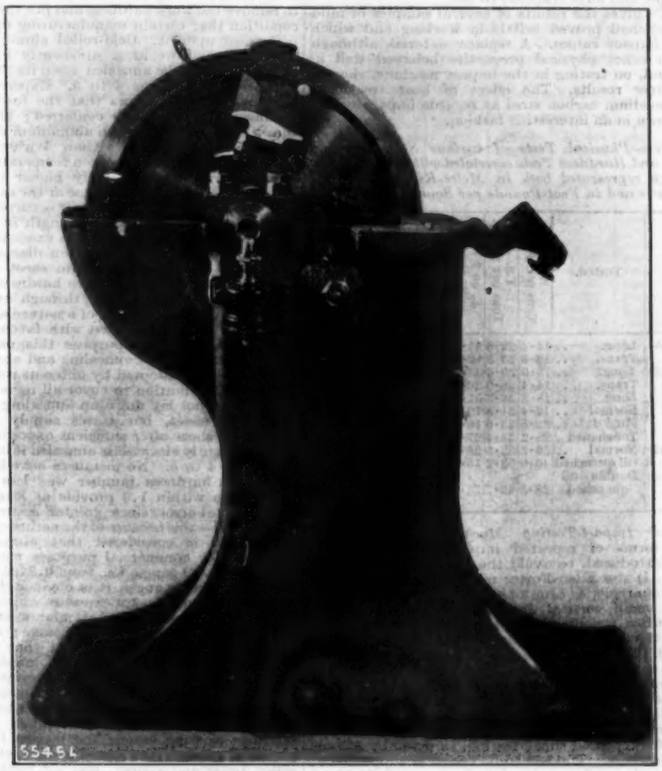


FIG. 16. GUILLERY IMPACT-TESTING MACHINE.

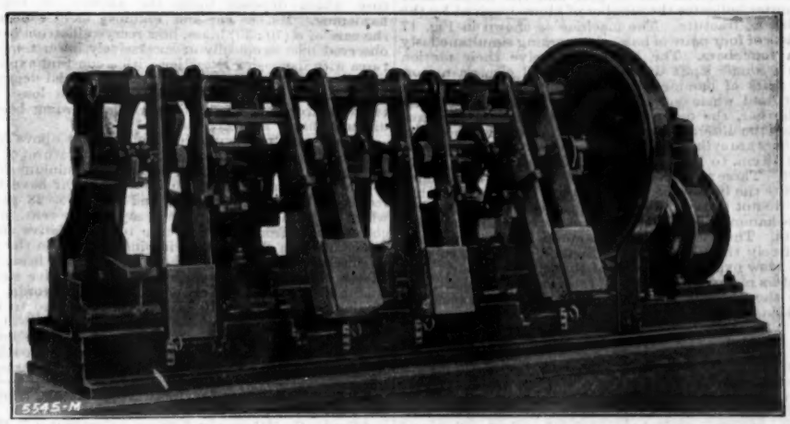


FIG 17. AMSLER QUADRUPLE-HAMMER MACHINE FOR REPEATED SHOCK TESTING.

This moves up or down a float inside the centrifugal pump shown in Figs. 14 and 15, and the vanes of this (rotated by bevel wheel from the axis of the flywheel) serve to raise a coloured liquid in the speedometer tube.

A view of the machine taken with the cast-iron top cover removed from the lower casing and pedestal, shows in Fig. 16 the simple mechanism whereby the breaking knife is attached to the flywheel, so that when in the closed, or "in" position, the knife is completely encased within the rim of the flywheel. When the red stud is pressed, the spring forces the knife into the open or "out" position required for breaking the test bar. The knife is made to assume these positions by means of the rotation of the flywheel itself, according as the closing or opening button is pressed on the outside of the lower casing. In working the machine, it is only necessary to

restore the energy lost in each test to make the machine ready for the next test. The danger of the open knife is obviated by a simple device which prevents the door (enclosing the test bar when in position) from being opened so long as the knife is out and the flywheel still rotating. The small and safe design of this machine, in which all the moving parts are enclosed, the lack of overhang and stability even without bolting down, so long as it rests on a level floor, and the direct reading of the energy absorbed, makes this machine one of the most simple and advantageous to use.

Table IV gives the results of several samples of mild steel which had proved brittle in working and which gave low impact values. A replace material, although similar in other physical properties behaved well in service, and, on testing in the impact machine, showed much better results. The effect of heat treatment on some medium carbon steel as regards impact values is also shown in an interesting fashion.

Table IV.—*Physical Tests of various Steels showing Tensile and Hardness Tests correlated with the Resistance to Shock represented both in Metre-Kilogrammes per Centimetre and in Foot-Pounds per Square Inch.*

Steel.	Tested.	E.L. Tons per Sq. In.	T.S. Tons per Sq. In.	E. on 2 In. Per Cent.	R.A. Per Cent.	Brinell Hardness	Impact Values. M.K.G.	Impact Values. Ft.-Lb.
Mild C 0·15	Long. ..	14·4	23·6	41·6	67·3	100	8·0	373
,, C 0·18	Trans. ..	12·6	23·8	19·5	50·5	105	5·0	233
,,	Long. ..	15·0	29·0	33·2	51·8	115	12·6	580
,,	Trans. ..	14·4	28·0	26·3	35·0	110	15·0	700
,,	Long. ..	18·2	26·3	51·0	53·0	110	27·0	1,260
Mild C 0·2	Normal ..	12·4	21·8	10·0	9·0	105	8·2	380
,,	Forged ..	22·8	33·6	16·8	20·6	150	9·5	445
,,	Toughened	25·2	34·4	27·9	40·9	145	15·5	725
Med. C 0·34	Normal ..	20·2	33·5	28·0	48·0	122	10·0	467
,,	Oil quenched	40·0	52·2	15·0	54·0	230	19·0	890
,,	Double oil quenched	28·5	43·7	26·0	62·0	180	27·0	1,260

Repeated Impact-Testing Machines.—One of the simplest forms of repeated impact-testing machines recently introduced, to avoid the chattering sometimes met with, is the Eden-Foster machine, which is made in this country. A cam operates a lifting chain to engage a small vertical drop hammer, which is only released when the lifting mechanism is lowered to be clear of the fall. Two different weights of tup are used, and the whole apparatus is small and compact, although capable of taking the standard notched bar for this test. The bar is rotated in a simple friction clutch method whilst securely held in two plummer blocks.

A different principle is used in the quadruple hammer machine for repeated shock testing, as made by Messrs. Amsler Brothers. The bar to be tested is supported at the two ends, and a pair of hammers deal it blows alternately from right and left until it breaks. The fracture is thus produced by fatigue. At the moment of fracture of the bar, the mechanism actuating the hammers is thrown out of gear and the blows cease. A counter indicates the number of blows received by the bar before fracture. The machine as shown in Fig. 17 consists of four pairs of hammers working simultaneously upon four bars. The hammers receive their motion from a single shaft driven by a small electric motor. The pairs of hammers are quite independent of each other, and when one pair stops owing to the fracture of the bar, the other pairs continue their movement, so that the different bars are tested quite independently. The bars are cylindrical in shape, and 12 mm. in diameter, from 18 cm. to 19 cm. long, as their supports are 17 cm. apart. These supports can turn on a vertical axis, which permits the bars to be bent freely by each blow, so that they do not behave like tightly-gripped bars. The blow of the hammers is delivered at two diametrically opposite points. The weight of each hammer is 5 kg., and they fall freely through a vertical height of 5 cm., so that each blow expends ½ m.-kg. of energy on the bar. The counters record the number of rotations of the shaft, and thus the pairs of blows struck. The usual speed of rotation is about 90 r.p.m.

Durability and Strength of Ferro-Concrete Vessels.—Our contemporary, *Ferro-Concrete*, gives the following information: A 150-ton barge built about 1906 for the Italian Navy was put to the severe test, before acceptance, of being driven against piling and then rammed by a steel tow-boat. The Mouchel–Hennebique lighter of 200 tons capacity, built in 1912, on the Manchester Ship Canal, has been in constant service since completion, only a trifling expense having been needed for maintenance. An 80-ft. barge, on the Welland Canal, Canada, has been in almost constant service since 1910 with no maintenance charges, and is still in excellent condition. At times she has been loaded with 10-ton car load of stone dumped from a height of 12 ft. to 15 ft. directly upon the 2½-in. deck. A lighter built at Baltimore in 1912 has been in daily use since construction, is perfectly watertight, and has withstood the roughest handling, requiring no pumping out and accumulating no barnacles or sea growths of any kind. Another lighter at Baltimore, built about 1913, has not required a dollar's worth of repairs since being put in commission. The historic Lambot boat, dating from 1849, is still in use and in excellent condition. A schooner built in 1899 for the North Atlantic coasting trade was once driven on the rocks off Cape Charles, and got off uninjured.

ANNEALING COLD-ROLLED ALUMINIUM SHEET.

*Annealing Cold-Rolled Aluminium Sheet by Abbreviated Exposures at Various Temperatures.**

By Robert J. Anderson, B.Sc., Met.E., Member, Cleveland, Ohio, U.S.A.

In commercial mill practice cold-rolled aluminium sheet is annealed by rather prolonged exposures at various temperatures—*e.g.*, 24 hours at 370 deg. C.—in order to remove the work hardness and put the metal into such condition that certain manufacturing operations can be performed upon it. Cold-rolled aluminium sheet after sufficient exposure at a sufficiently high temperature has been said to be annealed when its Shore scleroscopic hardness number was 4 to 5. Experimental evidence is at hand which shows that the foregoing degree of hardness can be rapidly conferred; the evidence also shows that even though an aluminium sheet has a Shore hardness number of less than 5 when exposed for a relatively short time at a given temperature, the ultimate strength will be appreciably higher than for similar metal exposed for a longer time at the same temperature. Recrystallisation may not have occurred in either case, so that the lower ultimate strength in the metal for a longer time has not arisen from excessive grain growth.

For the purpose of the present discussion, the author is defining annealed aluminium sheet as that product secured by conferring a Shore hardness number of 4–5 upon cold-rolled aluminium through exposure to heat. While arbitrary definitions of a nature similar to the one just given are not regarded with favour, still it is held that for the present purpose this one is justifiable. Various definitions of annealing and annealing temperatures have been adopted by different workers, and there is no broad definition to cover all metals. The present author does not lay down an annealing temperature for aluminium sheet, but states simply that cold-rolled aluminium sheet after sufficient exposure at a temperature sufficiently elevated is annealed if its Shore hardness number is 4 to 5. No instances have been noted where the Shore hardness number was less than 3.5, and readings to within 1.0 provide at least for fairly safe experimental error, since greater accuracy can scarcely be expected—this because of the nature of the scleroscope.

When it is considered that aluminium sheet as furnished for commercial purposes may be from, say, No. 3 to No. 30 gauge, *i.e.*, from 0.2294 in. to 0.0100 in. thick, or lighter gauges, it is obvious that an annealing temperature and time of exposure which are appropriate for heavy gauge cold-rolled aluminium are not necessarily appropriate for metal of light gauge; and, in fact, the casual conjecture would suggest that totally different annealing methods should be employed. Such an observation is entirely in accordance with our knowledge concerning the effects of heat upon metals in general which have received different amounts of previously cold work. Possibly the first clear account of the relations existing among the factors temperature and period of exposure and prior cold work, in the case of rolled brass and copper, was set forth by Captain C. Grard† as recently as 1909; certainly no full cognizance of the complications of these factors was taken by Le Chatelier.‡ The latter, however, suggested that the effect of annealing begins to be apparent at a temperature which depends upon the amount of original hardening. Mathewson and Phillips§ have shown, in the case of α (70 : 30) brass, how recrystallisation can be observed microscopically at successively lower temperatures with increasing reduction with a constant exposure period. The idea that the greater the initial degree of reduction in the cold for aluminium the lower the temperature at which the effects of annealing become distinguishable has been substantiated.‖

Transferring now our attention from the above brief, and very incomplete, review of the literature of the subject, let us consider two cold-rolled aluminium sheets—one No. 8 gauge, which in the mill might have been reduced about 47 per cent., and one, No. 28 gauge, which might have been reduced, say, 95 per cent. in the cold. Apart from any reference to the relative thicknesses of these sheets as having influence upon the rate of mechanical softening when exposed to heat, the effects of heat become earlier apparent, under similar conditions, in the latter one. In other words, the No. 28 gauge sheet will soften upon exposure to heat more rapidly, under similar conditions, than will the No. 8 gauge sheet. The complications which ensue, however, when deformed metal is heated, as outlined by Howe¶ and reviewed by Carpenter and Taverner,** are such that further investigations are required to explain certain aspects of the subject. With the knowledge that aluminium is sluggish in recrystallising, and assuming that relief of stress, re-orientation, and grain growth probably do not contribute markedly to mechanical softening, it follows that they are not indispensable in order to soften cold-rolled aluminium sheet.

By the definition above given and from the so-called practical standpoint, aluminium sheet is stated to be "dead soft" when its Shore hardness number is 4 to 5, and metal with this degree of hardness—providing it has not been over-annealed (in the sense that it has been exposed to heat at too high a temperature, or for too long a time, or both, so that undesirable weakness has been conferred)—is in a condition so that by the works' processes, such as stamping, drawing, spinning, &c., it can be worked with ease.

A consideration of what has gone before led the author to propose three inquiries. First, is not the annealing of cold-rolled aluminium sheet for, say, 24 hours at about 370 deg. C. disproportionate to the requirements for metal that is to be worked in the draw press? Second, may not cold-rolled aluminium sheet be softened by relatively short annealing exposures at the same or somewhat more elevated temperatures? Third, will metal so softened be suitable for commercial draw-press manipulation?

The first inquiry may be considered to have been more or less fully answered elsewhere.* Suffice it to say here, without setting forth an extended survey of the evidence which supports the belief, that, for annealing cold-rolled aluminium sheet which is to go to the draw-press, the 24-hour time exposure at 370 deg. C. is altogether too long. Annealing experiments have shown that most of the mechanical softening, effected by exposure to heat at various temperatures, of cold-rolled aluminium, takes place during the earlier part of a given exposure period. Thus, in the tests of Carpenter and Taverner,† about 80 per cent. of the fall in ultimate strength occurred in 1 hour at 350 deg. C., and in the author's experiments 12-gauge cold-rolled aluminium sheet (reduced 63.3 per cent.) had a Shore hardness number of 15 and an Erichsen indentation value of 9.49 mm. as rolled, while after an exposure of 30 minutes at 300 deg. C. the values were 7.1 and 10.97 mm. respectively, and after an exposure of 60 minutes at the same temperature the values were 4.9 and 11.70 mm. respectively. Also, in annealing the same metal at 400 deg. C., after an exposure of 5 minutes, the Shore hardness number was 10.6, while after a 10-minute exposure the Shore hardness number was 4.9. Sir Thomas Rose,‡ after studying the annealing of certain coinage alloys, made the following comments: "The annealing action at any given temperature is most rapid at first and gradually dies away, so that a state of equilibrium is not attained in any short space of time, except perhaps at high temperatures. For example, equilibrium apparently was not attained in the gold-copper, silver-copper, or nickel-copper alloys, or in pure nickel, in 16 days at 300 deg. C. At high temperatures almost the whole result is obtained instantaneously, though a little extra softness is got by prolonging the time. A few minutes at such a temperature cannot be replaced, for practical purposes, even by hours of annealing at much lower temperatures."

Now, for many drawing processes in the production of aluminium shapes, it is not rigidly demanded that the annealed sheet should have the lowest ultimate strength value consistent with sound metal, nor is it necessary that the Shore hardness number be less than 4 to 5 (some samples of annealed sheet have been tested which had a Shore hardness number of 3.5); in fact, it is doubtful, although complete data are not at hand fully to warrant the conclusion, whether so-called complete annealing is desirable. It is probably advisable to state parenthetically that many of the draw-press operations performed upon softened aluminium sheet are conducted for the purpose of manufacturing such objects as kitchen utensils, or parts of built-up welded shapes of one sort or another. Cold-rolled aluminium sheet does not draw sufficiently to withstand without rupture such deep draws as are required in the commercial production of these objects; hence, for drawing purposes, the metal must be softened. On the other hand, over-annealed sheet will rupture in the press because of its inherently weak condition. Tests in the draw-press have shown that, other things being equal, aluminium sheet annealed for relatively short times better withstands the drawing operation than does that annealed for long times. Considering the preceding remarks broadly, it appears that the usual long-time annealing methods are unnecessary for aluminium going through the draw-press.

Returning now to the second inquiry (may not cold-rolled aluminium sheet be softened by relatively short annealing periods, &c.?); the previously quoted communication§ has shown that mechanical softening, as evidenced by the drop in scleroscopic hardness from 13 to 15, to 4 to 5, can be brought about, in specific

* Paper read before the Institute of Metals, September 11, 1918.

† Grard, C., "Cuivre et Laitons à Cartouches," *Revue d'Artillerie*, February–April, 1909.

‡ Le Chatelier, André, "Congrès Internationale des Méthods d'Essai des Matériaux de Construction, 1901," tome ii, pages 1 to 25.

§ Mathewson, C. H., and Phillips, A., "Recrystallisation of Cold-Worked Alpha Brass on Annealing," Bulletin of the American Institute of Mechanical Engineers, January, 1916, pages 1 to 50; see page 26, Table III.

‖ Anderson, Robert J., "Annealing and Recrystallisation of Cold-Rolled Aluminium Sheet," *Metallurgical and Chemical Engineering*, May 15, 1918, No. 10, vol. xviii, pages 523 to 527.

¶ Howe, H. M., "Recrystallisation after Plastic Deformation," Bulletin of the American Institute of Mechanical Engineers, October, 1916, pages 1851 to 1860.

** Carpenter, H. C. H., and Taverner, L., "The Effects of Heat at Various Temperatures on the Rate of Softening of Cold-Rolled Aluminium Sheet," Journal of the Institute of Metals, No. 2, 1917, vol. xviii, pages 115 to 155; see pages 122 to 126.

* Anderson, Robert J., *op. cit.*, "Erichsen Tests on Aluminium Sheets," *Iron Age*, No. 15, April 11, 1918, vol. ci, pages 950 to 951. Note: Erichsen indentation values for samples exposed for relatively brief periods of time were better than those for similar samples exposed for long times at the same temperature.

† Carpenter, H. C. H., and Taverner, L., *op. cit.*, Table XX, page 151.

‡ Rose, T. K., "The Annealing of Coinage Alloys," Journal of the Institute of Metals, No. 2, 1912 vol. viii, pages 86 to 125.

§ Rose, T. K., "The Annealing of Coinage Alloys," Journal of the Institute of Metals, No. 2, 1912, vol. viii pages 86 to 125.

instances, by heating for such a time as 10 minutes providing the temperature employed is high enough. This inquiry is conclusively answered in the present paper, where it will be shown in later paragraphs and in the subjoined tables that the lighter gauges of cold-rolled aluminium sheet can be softened by such an abbreviated exposure as 3 minutes at 400 deg. C. Finally, with regard to the third inquiry, tests in the mill, with aluminium annealed by short time exposures to heat, have demonstrated that metal so treated fulfils the draw-press requirements; and, further, that the percentage of defective shapes is smaller than with similar metal annealed by an exposure for, say, 24 hours at 370 deg. C.

Description of Experiments.—Before entering upon a detailed description of the experiments performed, it is advisable to point out that the annealing tests were made for a particular purpose, viz., the effort was extended to soften cold-rolled aluminium sheet by relatively short-time exposures at various temperatures, so that it could be worked in the draw-press. If this can be accomplished, it follows that a continuous furnace for annealing aluminium is not only a possibility, but is, in fact, definitely assured, provided that certain minor details of a mechanical nature can be overcome, and these latter should afford no great difficulty. Here, too, the statement may be made that most valuable indications as to the "drawability" of metal sheet are furnished by the recently brought out cupping test* as made in the Erichsen sheet-metal apparatus. This machine has recently been employed for testing some of the common brasses in sheet form.† The cupping test, in addition to furnishing information as to the drawing quality of metal sheet, gives evidence of the grain size—data which are highly important as a guide to the working of brasses. Knowledge as to the grain size of aluminium sheet is not so important, since the mechanical softening and coalescence ranges are evidently far apart.

The experiments made in the present instance were upon aluminium of the following analysis:—

	Per Cent.
Copper	0.25
Iron	0.45
Manganese	trace
Silicon	0.35
Aluminium (by difference)	98.95
	100.00

Now the objection may be offered that this should be regarded as an alloy of aluminium rather than relatively pure metal. However, although purer metal was obtainable, ingot-costing charges are usually mixed with a certain amount of scrap aluminium, so that the average cast ingots, as rolled in the mill making aluminium sheet, analyse about as shown above. It may be that the results would be more desirable from the scientific standpoint had the metal been higher in chemical purity.

The history of the aluminium sheets experimented with is as follows: The ingot was cast at a temperature of approximately 800 deg. C. and allowed to cool to room temperature; it was then raised to about 450 deg. C. in an ingot-heating furnace, being charged cold, and remaining for 6 hours in the furnace. The ingot was then withdrawn from the furnace and broken down to a 0.2291-in. slab in a 28-in. two-high hot mill. This resultant slab was then slabbed cold to 0.1215 in. and then rolled to a succession of gauges, viz., 10, 12, 14, 16, 18, 20, 22, 24, 26, and 28 (these figures representing gauge numbers). Numerous samples were cut from the various gauges of cold-rolled metal; these were about 3 in. by 9 in. in surface dimensions—sufficient area for three Erichsen tests and the necessary scleroscope

TABLE I.—*Erichsen and Scleroscope Values of the Cold-Rolled Sheets.*

Sample Marked.	Sheet Gauge.	Shore Hardness No.	Erichsen Values. Thickness in Mm.	Erichsen Values. Indentation in Mm.	Percentage Reduction.	Thickness in In.
1	3	5·0	5·96	—	—	0·2291
2	8	12·5	3·11	—	47·00	0·1215
3	10	14·0	2·58	10·01	54·85	0·1037
4	12	15·0	2·05	9·49	63·30	0·0841
5	14	15·0	1·70	8·24	71·60	0·0650
6	16	15·5	1·32	7·28	77·70	0·0512
7	18	15·0	1·02	6·58	82·60	0·0401
8	20	15·0	0·79	6·16	86·00	0·0321
9	22	15·0	0·68	5·92	88·00	0·0275
10	24	14·5	0·54	5·16	90·50	0·0220
11	26	15·0	0·40	4·57	92·70	0·0169
12	28	13·5	0·30	3·64	94·50	0·0128

determinations. The percentages of reduction, Erichsen indentation values, thicknesses, and scleroscopic hardnesses for the cold-rolled sheets are summarised in Table I.

* The cupping test is carried out on a hand-operated ductility testing machine, and is used for testing thin sheet metal up to about 0.0625 in. in thickness. The sample is held between a die and holder, and a tool actuated by a ram and a hand wheel is moved gradually forward, causing the formation of a cup, which eventually fractures. The depth of indentations is then read off directly from micrometer scales and forms the basis of workability determinations.

† Davis, C. H., "Testing of Sheet Brass," Proceedings of the American Society for Testing Materials, 1917, Part II, vol. xvii, pages 167, 193.

The samples were exposed to the temperatures and for the times recorded in the accompanying tables. The annealing was performed in a small electric furnace of the resistance type. Temperatures as given are accurate to ± 10 deg. C., and the variation in temperature in the different parts of the furnace was not greater than ± 10 deg. C. Temperatures were measured with the Northrup Pyrovolter, using base metal couples which had previously been calibrated by the usual methods. The samples were annealed by placing them in the already heated furnace, allowing them to remain for the required time, and then withdrawing them so that they cooled in air. Not over five samples were annealed at a time, and the individual pieces were separated by small pieces of light-gauge aluminium sheet, so that free access of heat could obtain in all parts of a pile. Conditions were maintained as nearly alike as possible, and all samples had identical treatment other than for the variable factors time and temperature. The samples were considered to be softened when the Shore hardness number was 4 to 5, and indentation values, secured with the Erichsen apparatus, served as a guide to their drawing qualities. Erichsen indentation values were not secured, in general, for samples that had a Shore hardness number of more than 5.

There was some difference in the measured thick-

TABLE II.—*Showing Variations in the Thicknesses of the Sheets.*

Sample Marked.	Sheet Gauge.	Measured Thickness in In.	Measured Thickness in Mm. from Erichsen Test.	Calculated In. from Measured Mm.	Calculated Mm. from Measured In.
1	3	0·2291	5·96	0·2384	5·73
2	8	0·1215	3·11	0·1244	3·04
3	10	0·1037	2·58	0·1032	2·59
4	12	0·0841	2·05	0·0820	2·10
5	14	0·0650	1·70	0·0680	1·63
6	16	0·0512	1·32	0·0528	1·28
7	18	0·0401	1·02	0·0408	1·00
8	20	0·0321	0·79	0·0316	0·80
9	22	0·0275	0·68	0·0272	0·69
10	24	0·0220	0·54	0·0216	0·55
11	26	0·0169	0·40	0·0160	0·42
12	28	0·0128	0·30	0·0120	0·32

Note.—The differences in the measured thicknesses of the sheets in inches compared to the measured thicknesses in millimetres calculated to inches, and *vice versa*, are due to the actual variations in the thicknesses at different places on a given sheet, and the fact that the measurements were made at different places.

TABLE III.—*Maximum Indentation Values obtained for the Briefest Exposure at the Lowest Temperature, together with Shore Hardness Number of 5 or Less.*

Sample Marked.	Sheet Gauge.	Exposure Time in Minutes.	Temperature in Deg. C.	Erichsen Values. Thickness in Mm.	Erichsen Values. Indentation in Mm.	Shore Hardness No.
3C	10	60	300	2·58	12·60	5·0
4E	12	30	350	2·05	12·20	5·0
5C	14	60	300	1·70	11·51	4·9
6Y	16	15	350	1·32	10·97	5·0
7E	18	30	350	1·02	9·98	5·0
8E	20	30	350	0·79	8·95	5·0
9D	22	10	350	0·68	8·75	5·0
10D	24	20	300	0·54	8·25	4·7
11E	26	30	350	0·40	7·70	4·5
12B	28	30	300	0·30	7·52	4·5

Note.—These figures are used for the thickness-indentation curve for annealed aluminium sheet in Fig. 1.

nesses of the coldrolled sheets as taken with the micrometer compared with the measured thicknesses in millimetres from the Erichsen test, and these calculated differences are given in Table II. In Table III are recorded the maximum indentation values obtained through a series of annealing tests on various gauges of

Fig. 1.

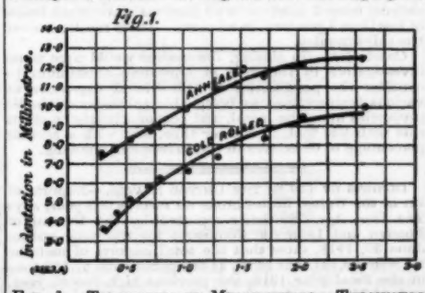


FIG. 1. THICKNESS IN MILLIMETRES. THICKNESS-INDENTATION CURVES FOR COLD-ROLLED AND ANNEALED ALUMINIUM SHEET.

this aluminium sheet; for a Shore hardness number of 5 or less these values represent the deepest indentation obtainable in the shortest time at the lowest temperature. The indentation values for similar samples annealed for shorter times but at more elevated temperatures are shown in the subjoined Tables IV to XI inclusive. Fig. 1 shows the indentation-thickness curves for cold-rolled and annealed aluminium sheet of the gauges tested. The curve data are taken from Tables I and III. With the Erichsen ductility test, the indentation is deeper with the increasing thickness of the sheet, other things being equal, and the annealed samples have deeper indentation values than the cold-rolled ones.

Discussion of the Results.—Table IV gives a summary of the tests on various gauges of cold-rolled aluminium sheet exposed for 3 minutes at 400 deg. C. The hardnesses of the various samples after this heating is progressively lower with increasing reduction. Gauges including and above No. 22 gauge were mechanically

TABLE IV.—*Results of Annealing Various Gauges of Cold-Rolled Aluminium Sheet. Time Constant at 3 Minutes, and Temperature Constant at 400 deg. C.*

Sample Marked.	Sheet Gauge.	Shore Hardness No.	Erichsen Values. Thickness in Mm.	Erichsen Values. Indentation in Mm.	Appearance of Dome.	Blisters on the Surface.
3W	10	12·4	—	—	—	none
4W	12	12·0	—	—	—	none
5W	14	11·9	—	—	—	none
6W	16	11·7	—	—	—	none
7W	18	11·4	1·08	7·78	smooth	none
8W	20	6·9	0·81	8·19	smooth	none
9W	22	5·0	0·70	9·01	smooth	slightly
10W	24	5·0	0·54	8·31	smooth	slightly
11W	26	4·8	0·40	7·90	smooth	many
12W	28	4·9	0·31	7·75	smooth	slightly

TABLE V.—*Results of Annealing Various Gauges of Cold-Rolled Aluminium Sheet. Time Constant at 3 Minutes, and Temperature Constant at 425 deg. C.*

Sample Marked.	Sheet Gauge.	Shore Hardness No.	Erichsen Values. Thickness in Mm.	Erichsen Values. Indentation in Mm.	Appearance of Dome.	Blisters on the Surface.
3Z	10	11·4	—	—	—	none
4Z	12	11·3	—	—	—	none
5Z	14	11·0	—	—	—	none
6Z	16	10·0	—	—	—	slightly
7Z	18	7·4	1·08	8·90	smooth	none
8Z	20	5·0	0·81	8·79	smooth	none
9Z	22	5·0	0·71	8·44	smooth	slightly
10Z	24	5·0	0·55	7·89	smooth	slightly
11Z	26	4·7	0·42	7·61	smooth	many
12Z	28	4·9	0·33	7·20	smooth	slightly

TABLE VI.—*Results of Annealing Various Gauges of Cold-Rolled Aluminium Sheet. Time Constant at 3 Minutes, and Temperature Constant at 450 deg. C.*

Sample Marked.	Sheet Gauge.	Shore Hardness No.	Erichsen Values. Thickness in Mm.	Erichsen Values. Indentation in Mm.	Appearance of Dome.	Blisters on the Surface.
3X	10	11·1	—	—	—	none
4X	12	10·3	—	—	—	none
5X	14	9·8	—	—	—	none
6X	16	6·5	1·34	10·10	smooth	none
7X	18	5·0	1·08	10·04	smooth	none
8X	20	4·9	0·81	9·10	smooth	none
9X	22	4·6	0·71	8·56	smooth	slightly
10X	24	4·7	0·54	8·05	smooth	slightly
11X	26	4·6	0·41	7·59	smooth	slightly
12X	28	4·6	0·33	7·30	smooth	many

TABLE VII.—*Results of Annealing Various Gauges of Cold-Rolled Aluminium Sheet. Time Constant at 3 Minutes, and Temperature Constant at 475 deg. C.*

Sample Marked.	Sheet Gauge.	Shore Hardness No.	Erichsen Values. Thickness in Mm.	Erichsen Values. Indentation in Mm.	Appearance of Dome.	Blisters on the Surface.
3V	10	11·1	—	—	—	none
4V	12	10·5	—	—	—	none
5V	14	10·2	—	—	—	none
6V	16	6·6	1·31	9·92	smooth	none
7V	18	5·0	1·08	10·00	smooth	none
8V	20	4·9	0·81	8·52	smooth	slightly
9V	22	4·9	0·71	8·41	smooth	slightly
10V	24	4·5	0·55	8·16	smooth	slightly
11V	26	4·4	0·42	7·70	smooth	slightly
12V	28	4·6	0·32	7·20	smooth	slightly

softened to Shore hardness number 5 by the treatment given; this does not imply that the metal so softened had been recrystallised, or even that any visible change in the microstructure had taken place. The rate at which aluminium recrystallises is a slow one, and in the case of metal deformed by cold-rolling appears to be extremely slow. Recrystallisation in copper and brass, on the other hand, is quite rapid. The fractured domes of the Erichsen tests were smooth, indicative of good drawing quality. The formation of blisters on the surfaces of the annealed samples is indicated in a rough way, based on ocular evidence, in the last column of the tables, and will be discussed a little later on. In Table IV the first sample to attain a hardness of 5 was the No. 22 gauge one (percentage of reduction, 88.0).

In Table V are recorded the data from the tests made

where the samples were exposed for 3 minutes at 425 deg. C. There is again a progressive drop in the Shore hardness number with increasing percentage of reduction, and the first sample to attain a hardness of 5 was the No. 20 gauge one (percentage of reduction, 86.0). The fractured domes were again smooth. The results of annealing for 3 minutes at 450 deg. C. are given in Table VI, and here the No. 18 gauge sheet (percentage of reduction, 82.6) was the first to be softened to Shore hardness number 5. When annealed at 475 deg. C. for 3 minutes, the first sample to attain Shore hardness number 5 was again the No. 18 gauge one, as shown in Table VII; while in Table VIII, where the annealing was performed at 500 deg. C., the first sample so to soften

TABLE VIII.—*Results of Annealing Various Gauges of Cold-Rolled Aluminium Sheet. Time Constant at 3 Minutes, and Temperature Constant at 500 deg. C.*

Sample Marked.	Sheet Gauge.	Shore Hardness No.	Erichsen Values.		Appearance of Dome.	Blisters on the Surface.
			Thickness in Mm.	Indentation in Mm.		
3Y	10	10·5	—	—	—	none
4Y	12	10·5	—	—	—	none
5Y	14	10·5	—	—	—	none
6Y	16	4·9	1·34	10·00	smooth	none
7Y	18	4·9	1·08	9·88	smooth	none
8Y	20	4·8	0·81	8·72	smooth	none
9Y	22	4·6	0·71	8·31	smooth	slightly
10Y	24	4·5	0·55	7·85	smooth	slightly
11Y	26	4·4	0·42	7·66	smooth	slightly
12Y	28	4·4	0·32	6·95	smooth	slightly

TABLE IX.—*Results of Annealing Various Gauges of Cold-Rolled Aluminium Sheet. Time Constant at 5 Minutes, and Temperature Variable.*

Sample Marked.	Sheet Gauge.	Temp. deg. C.	Shore Hardness No.	Erichsen Values.		Appearance of Dome.	Blisters on the Surface.
				Thickness in Mm.	Indentation in Mm.		
3XX	10	450	9·5	—	—	—	none
4XX	12	450	8·1	—	—	—	none
5XX	14	450	5·5	1·68	11·12	smooth	none
6XX	16	400	5·5	1·36	10·74	smooth	none
7XX	18	400	5·9	1·06	9·80	smooth	none
3XXX	10	500	5·2	2·56	12·30	smooth	none
4XXX	12	475	5·5	2·09	12·09	smooth	slightly

TABLE X.—*Results of Annealing No. 28-Gauge Cold-Rolled Aluminium Sheet. Time Constant at 1 Minute, and Temperature Variable.*

Sample Marked.	Temp. deg. C.	Shore Hardness No.	Erichsen Values.		Appearance of Dome.	Blisters on the Surface.
			Thickness in Mm.	Indentation in Mm.		
12AA	400	9·5	—	—	—	none
12BB	450	8·0	0·53	6·00	smooth	slightly
12CC	500	5·2	0·32	7·19	smooth	slightly

TABLE XI.—*Results of Annealing No. 28-Gauge Cold-Rolled Aluminium Sheet. Time Constant at 2 Minutes, and Temperature Variable.*

Sample Marked.	Temp. deg. C.	Shore Hardness No.	Erichsen Values.		Appearance of Dome.	Blisters on the Surface.
			Thickness in Mm.	Indentation in Mm.		
10DD	400	5·0	0·32	7·48	smooth	slightly
12EE	450	5·0	0·31	7·50	smooth	slightly
12FF	500	5·0	0·31	7·47	smooth	slightly

TABLE XII.—*Showing the Temperature required to Produce a Scleroscopic Drop of from 14 to 15 to 4 to 5 in 3 Minutes for Different Percentages of Reduction.*

Sheet Gauge.	Percentage of Reduction.	Temperature Deg. C.
22	88·00	400
20	86·00	425
18	82·60	450
18	82·60	475
16	77·70	500

was the No. 16 gauge one (percentage of reduction, 77.7). Sheets which were No. 14 gauge and heavier did not soften to Shore hardness number 5 with an exposure of 3 minutes at temperatures from 400 deg. to 500 deg. C.

The results of 5-minute exposures on Nos. 10, 12, 14, 16 and 18-gauge sheets at different temperatures are recorded in Table IX; those for 1 minute exposures on No. 28-gauge sheet are given in Table X, and those for 2-minute exposures on the same gauge in Table XI. The data bear out for cold-rolled aluminium sheet that mechanical softening is influenced by three factors at least; viz., (1) the percentage of reduction; (2) the time of annealing; and (3) the temperature of annealing.

Without going into an extended comparison of the results afforded by these and other experiments, it may be stated with confidence that cold-rolled aluminium sheet can be softened by relatively abbreviated exposures to heat at various temperatures—elevated somewhat, it is true, above those commonly employed. Table XII shows in condensed form how the effects of softening become apparent at lower temperatures, using a constant annealing exposure, with increasing percentage of reduction. Fig. 2 gives curve plots showing the drop

Fig. 2.

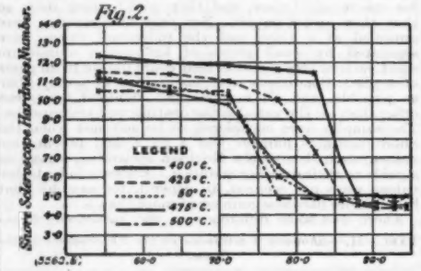


FIG. 2. REDUCTION IN PER CENT. SHOWING DROP IN SHORE HARDNESS NUMBER, WITH INCREASING REDUCTION, RESULTING FROM THREE-MINUTE EXPOSURES AT VARIOUS TEMPERATURES.

in scleroscopic hardness with increasing percentages of reduction resulting from exposures of 3 minutes at various temperatures. With increasing temperature the drop proceeds more rapidly, and the shape of the curves is, in general, the same.

Blisters and Blistering.—In mill-annealing practice it is found that some aluminium sheets blister while others do not, although both have had identical heat treatment. Blistered sheets are a source of great annoyance in the mill operation, and means for controlling and reducing the percentage of blistered sheets are urgently needed. From the present results, it appears that the tendency toward blistering increases with the increased thinness of the sheets; however, for the times and temperatures employed, visual examination showed that the blistering was not so severe, except in a few cases, as to ruin the sheets. What blistering did occur was usually very slight, and required careful examination to observe it. The formation of blisters also seems to be associated with the higher temperatures, *i.e.*, the tendency increases with more elevated temperatures. Annealing tests made in an oxygenated atmosphere, obtained by leading tank oxygen into the furnace, showed that this condition of the furnace atmosphere did not influence the formation of blisters. Tests in a reducing atmosphere were not performed. While conclusive evidence is not at hand, blisters appear to be associated with the escape of occluded gases from the metal on heating, and it has been observed that blisters invariably form at or near the position of occluded dross in the sheets.

Results of Tests on Worked Metal.—With a brief account of certain tests of worked aluminium sheet annealed by short-time exposures, the present paper will be concluded. In the manipulation of certain shapes by the draw-press, cold-rolled aluminium sheet is ordinarily cut into circles or other geometric pattern and then annealed before being drawn. It has been observed that if the annealing is effected by an exposure of, say, 24 hours at about 370 deg. C., that a heavy percentage of defective shapes results from the draw-press operation. In an observed instance on a large number of drawn blanks (4,400) this was 30 per cent. In order to test the effectiveness of short annealing, 200 cold-rolled No. 22-gauge circles were annealed for 3 minutes at 475 deg. C. and drawn in a typical draw-press operation into a given shape; there was but one defective shape resulting from rupture in the press, or a scrap loss of 0.5 per cent. Other tests made on various gauges of sheet which had been annealed for relatively short times, ranging from 5 minutes to 60 minutes, gave scrap losses of less than 1 per cent. in all cases. These results answer the third inquiry.

Conclusion.—In closing, the author would urge upon investigators in the field of annealing aluminium to consider the possibilities of abbreviated exposures at various temperatures as being able to confer workable properties upon the metal, and concomittantly to effect this with less fuel, in shorter time, and with a smaller percentage of defectives in the subsequent drawing.

IMPORTS OF TIN IN THE UNITED STATES.—Imports of tin in the United States broke all records last year, says *The Iron Age*. Statistics reported by the Bureau of Foreign and Domestic Commerce for the year ending June 30, 1918, show that the total imports of metallic tin were 69,731 tons gross, as compared with 67,529 tons in the fiscal year 1916, the previous high record year, and 44,722 gross tons in the fiscal year 1914, the last pre-war year. Interesting to note is the fact that while in 1914 the American imports of tin from the United Kingdom and from the Straits Settlements formed 90 per cent. of the total, in 1918 they amounted to only 55 per cent. of the total. The difference was compensated for by heavier shipments from Bolivia, China, Australia and the Dutch East Indies. The growth of the American infant tin-smelting industry is shown by the fact that approximately 13 per cent. of the American 1918 imports came to the United States in the form of ores, mostly from Bolivia.

CATALOGUES.

Truck Tipping Machine.—A series of machines which empty 300 railway trucks per day is illustrated in a catalogue received from the Wellman-Seavers-Morgan Company, Cleveland, U.S.A. These machines deal with open-top trucks; lifting, emptying and returning them. The discharge is generally into storage bins, blast-furnace heaps, boats or ships. A variety of plant, with various degrees of travelling and hoisting gear is made to suit these various purposes; also a hoisting frame for high storage bins.

Oxy-Acetylene Welding and Cutting.—Messrs. Charles Churchill and Co., Limited, 9, Leonard-street, Finsbury, London, E.C. 2, have issued a special catalogue of their oxy-acetylene welding and cutting outfits. These outfits range from small portable sets to large fixed installations with twin sets of four gas generators taking a charge of 1 ton of carbide. The complete outfits are shown including generators, tanks, drums, hose, blowpipes, cutters, piercers, valves, gauges, wire and cast material and sundries down to spectacles and gloves. Everything is illustrated and priced.

Spring Roller Bearings.—These bearings—square section spring steel coiled to form the roller—are being increasingly used on trucks, cranes and transport appliances generally. They are capable of withstanding a certain amount of shock better than solid rollers or balls. A catalogue from the makers, Messrs. Broom and Wade, Limited, High Wycombe, contains line illustrations and full particulars of dimensions of complete bearings in the form of axle boxes, truck wheels, jib crane pintles, mono-rail telphers, socket plummer blocks, &c. All very exactly and strongly made.

Centrifugal Pumps.—A very useful and clearly-written treatise on centrifugal pumps forms the introductory portion of a catalogue received from Messrs. Holden and Brook, Limited, West Gorton, Manchester. It is claimed that the only case in which the centrifugal pump is more costly and less efficient than the reciprocating is where a small quantity of water has to be lifted a considerable height. The idea of making several impellers to work in series originated in this country, but it was taken up and developed abroad in quantity production. British makers have, however, given closer attention to the essential principles of the machine. For some years they have produced in large quantities, but they realised that it was not economical in cheap form. Design of form is important, but material is at least equally so. The stresses are heavy when the pump is in action and the erosive forces very powerful; in idleness the corrosive forces come into play with almost violent intensity. It is, therefore, necessary to find the right material, and it has only been found by costly practical experiment. The economy in action is so great, provided the pump be durable, that it pays well to put in the best material and workmanship to make it durable. Even then the first cost is low as compared with reciprocating pumps. The catalogue fully describes all the parts, with plentiful illustration, and in addition to discussing theoretical questions deals lucidly and exhaustively with such practical matters as running, maintenance, repairs, erection, suitability for various kinds of work, &c. A liberal supply of technical data is given, including water friction in pipes and transmitting efficiency of belts and ropes. It is interesting to note that woven belts are generally of greater efficiency than single leather, and nearly equal to light double leather. Heavy double leather is decidedly superior even at 900 ft. speed and markedly so over 2,000 ft. speed. The comparison is with best oak-tanned hides. The pump is, of course, particularly suitable for electric motor direct drive.

Wood-Cutting Machine Tools.—In this country wood working machines are seldom called "machine tools." We restrict that term generally to metal-working machines. The wood workers' machines are, however true machine tools, because they are adapted hand tools embodied in power-driven machines. Other countries include both metal and wood-working machines in their category of machine tools—a point which causes error in comparisons of foreign trade. A catalogue from Messrs. Thomas Robinson and Sons, Limited, engineers, Rochdale, entitled "Wood-Working Machinery for Aircraft Manufacture," extends to 114 pages quarto. It gives illustrations and particulars of 16 sawing machines with circular, band and fret saws including vertical spindle and pendulum forms of the circular saw machine. In addition there are 25 other machines for planing, thicknessing, surfacing, moulding, boring, recessing, shaping, tenoning, mortising, &c., and some grinding, filing and other machines for dressing the cutting tools. Many of these have automatic feed and special adaption, or attachments, for aircraft work. The "Portable Rotary Shaping Apparatus" is a patent invention for shaping propeller and other surfaces not within the usual machine compass. It does the work of the spokeshave and drawknife hand tools. It may be described as a milling cutter with helical teeth. The cutter is covered by a casing open at the bottom and the case is movable so that the depth of cut may be adjusted. The cutter spindle is driven direct by a small electric motor and the whole machine slung over the work table. The weight of the machine is balanced by a deadweight and carried by a pulley mounted on a runway. It may, therefore, be easily moved over the workpiece or lifted clear of it—it is in this sense that it is called portable. In another form the cutter and spindle may be driven by a flexible driving shaft from a countershaft or fixed motor. The design is very neatly worked out to deal with a great variety of awkward jobs. The catalogue includes a wide range of machines, simple and complex, of substantial build, with ample bearings and adjustments and well guarded for the safety and comfort of the operators.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACT OF 1907.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

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AGRICULTURAL APPLIANCES.

116,855. J. T. Ridealgh, Headingley, Leeds. Steam Tractors. (3 *Figs.*) January 12, 1918.—This invention relates to ploughing steam tractors of the kind in which the steering movements of the vehicle are effected from the front axle alone, the rear axle being carried on springs and adapted to be driven from the engine through the medium of a side chain, but otherwise rigidly mounted on the main frame so as only to permit of the rotation of the wheels in the longitudinal plane of the vehicle. According to this invention, a vertical boiler is mounted low down on the carrying frame 1 between the front road wheels 4 and the rear road wheels 3, the engine 12 being mounted directly on the carrying frame in front of the boiler and behind the axle of the front road wheels, while the water tank is situated directly on the carrying frame behind the boiler and over the axle of the rear road wheels. The carrying frame is preferably made up of horizontally-arranged side and end girders of channel section, and the boiler is passed down between the two

Fig. 1.

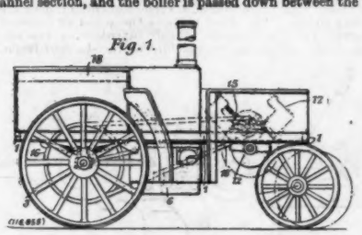
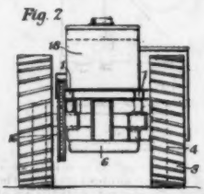


Fig. 2

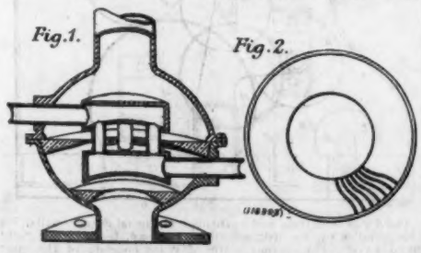


side girders of the frame and fitted immediately below its centre with an encircling band by which it is secured to the frame with the fire-box and footplate of the said boiler occupying a position below the latter and approximately near to the ground. The engine is preferably of the staggered-cylinder type in which the inlet and exhaust valves are operated from a single camshaft, and the axle of the rear road wheels is fitted with a chain wheel 15 carrying a side chain 16 passed around a chain wheel fixed on the camshaft by which the drive is obtained directly from the said camshaft. By employing a vertical boiler and arranging the boiler low down between the front road wheels and the rear road wheels and by fixing the engine on the frame at the front of the boiler and the water tank on the frame behind the boiler, a material reduction in the length and height of the tractor as a whole is ensured in conjunction with increased efficiency; while by driving the rear road wheels by a chain from the camshaft of the engine direct, a more simple and efficient drive is obtained. (*Accepted July* 3, 1918.)

GAS ENGINES, PRODUCERS, HOLDERS, &c.

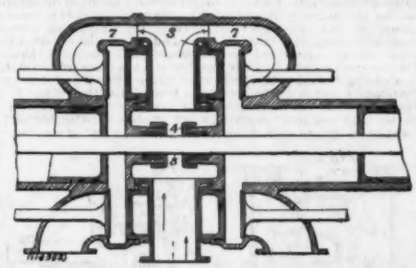
116,303. H. C. Carter, Bromley, and W. T. Vint and H. Alexander, Leeds. Vaporising and Atomising Liquid Fuel. (9 *Figs.*) March 10, 1917.—This invention comprises means for vaporising and atomising liquid fuel and for the production of combustible mixtures for motive power purposes. A vertical part of the induction pipe is formed with a globular casing or swelling. At the lower part of the casing and just above the neck portion, there is fitted an inwardly-projecting

Fig. 1. *Fig. 2.*



deflector, with a horizontal upper surface and an inclined, curved, or part-spherical lower surface formed with spiral or curved grooves, producing projections or fins so that the upwardly-flowing vapour or mixture striking against such surface is given a whirl, in addition to the plain deflecting effect. Within the casing is mounted a baffling device, also formed as a radiator, consisting of upper and lower headers, connected by vertical tubes. Each header is connected to a pipe, the two pipes being connected with the hot-water system of the cooling jackets of the engine, or with the exhaust duct. Thus, hot water or fluid enters the one and upper header and flows through the vertical tubes into the other and lower header, from which it passes back to the cooling or exhaust system by the other pipe. A second larger and wider deflector is mounted in the mouth of the lower casing part, and about midway between the two headers. This deflector may be of similar cross-section to the first, and is advantageously formed with spiral or curved grooves, projections or fins on its under surface. In operation, the upwardly-flowing stream, immediately after passing the throttle, encounters the lower deflector, which deflects it and, by its fins, also imparts a whirling motion. The deflected and whirling streams then immediately rise against the bottom surface of the lower header and are baffled and deflected downwardly and outwardly. In this way cross currents are produced, resulting in thorough intermixing of the constituents of the mixture, and the lower surface of the header not only further atomises the fuel but imparts heat to the mixture so that condensation is avoided and the predetermined character of the mixture is maintained. In further rising, the stream next strikes against the upper deflector, by which it is deflected and whirled, and then strikes against the bottom surface of the upper header by which it is further acted upon, so that finally the mixture leaves the induction pipe and enters the engine cylinder in the most favourable condition for efficient combustion. The radiator not only prevents condensation but also vaporises any moisture carried by the air. (*Accepted June* 19, 1918.)

116,552. S. S. Guy, Finchfield, Wolverhampton. Internal-Combustion Engines. (3 *Figs.*) June 19, 1917.—This invention relates to internal-combustion engines of the type in which two or more working cylinders are arranged co-axially or in tandem and in which the piston rod between such co-axial working cylinders works through a gland or glands subject to the temperature of the working fluid in the said cylinders. According to the present invention, the explosive mixture in passing from the source of supply to the cylinder inlet port or ports 7 is made to circulate around the piston gland or glands 4 and the valve ports. In this way the temperature of the gland, cylinder head or heads and the exhaust port or ports therein is kept within safe working limits, whilst incidentally the heat extracted from the said parts has the beneficial effect of warming up the explosive mixture prior to its entering the combustion chamber. A particularly advantageous application of the invention may be made in the case of a tandem engine



of the type in which the cylinder heads are adjacent to each other with a gland or glands between them, *i.e.*, the type of engine in which the pistons are simultaneously moving in opposite directions in relation to their respective cylinders. In such a case as this the two cylinder heads are enclosed within a cored or built-up chamber communicating with the inlet ports 7 and into which the glands 4 project with the piston rod 5 passing through them. The chamber 3 is provided with an orifice to which the induction pipe from the carburettor is adapted to be connected, and the arrangement is such that the cool explosive mixture in passing through said chamber to the inlet ports comes into direct contact with the glands 4 and cylinder heads and effectually maintains them at a proper working temperature. The invention is equally applicable whether the engine is air or water-cooled, except that in the latter case the explosive mixture in traversing the chamber would not come in direct contact with the cylinder heads with the water jackets thereon, although in each case it would impinge directly upon the glands. (*Accepted June* 26, 1918.)

116,870. The E. W. Harvey Gas Furnace Company, Limited, and E. W. Harvey, Westminster, London. Regenerative Gas Furnaces. (12 *Figs.*) March 5, 1918.—The "uni-directional" regenerative gas furnace has hitherto consisted of a long hearth, one end of which is heated to a relatively high temperature by a reversible flame, the rest of the hearth (the pre-heating hearth) being heated by a portion of the same flame drawn along it in a continuous direction. The ingots being introduced at the end far from the gas and air ports are heated progressively by the drawn-out flame as they are pushed along the pre-heating hearth and receive their final high temperature when they arrive on the finishing hearth near the gas and air ports. By the present invention, the gas is delivered to the furnace in continuous streams through two or more ports, and

Fig. 1.

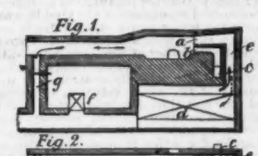
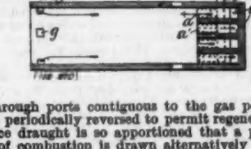


Fig. 2.



the air through ports contiguous to the gas ports in streams which are periodically reversed to permit regenerative heating; the furnace draught is so apportioned that a part of the hot products of combustion is drawn alternatively through one of two regenerators, while the remainder is drawn continuously in a straight direction along the preheating hearth. Four air ports *a*, *a*1, are placed all in the same plane immediately above four gas ports *b*, also in the same plane. The ports *b* are supplied with gas in a continuous stream (no gas reversing valve being used) from a producer through a flue *c* in which the gas is pre-heated owing to the situation of the flue close to the regenerators *d* and to the flues *e* leading from the latter to the air ports *a*, *a*1. During one period, part of the furnace draught draws air through valve *f*, regenerator *d*, alternate flues *e* and the corresponding air ports *a* (as indicated by full-line arrows) and a part of the products of combustion through ports *a*1, the flues *e* connected with these and the other regenerators (as indicated in dotted line arrows); during the next period, the air valve having been reversed, the ports *a*1 become the air admission ports and *a* the ports for the products of combustion. The several continuous streams of gas meet the hot air entering from the ports placed above them and the flames produced heat the finishing hearth to a relatively high temperature and thence are drawn along the preheating hearth, heating it uniformly throughout its width, by the portion of the furnace draught which is exerted through flues *g*. (*Accepted July* 3, 1918.)

LIFTING AND HAULING APPLIANCES.

116,791. Allen West and Co., Limited, Brighton, and L. Satchwell, Roath, Cardiff. Lifting Magnets. (4 *Figs.*) July 20, 1917.—This invention relates to lifting magnets. The invention consists broadly in providing the magnet with a non-inductive resistance permanently in shunt with the magnet and connected directly across its terminals. R designates a non-inductive resistance, preferably of carbon, which is connected directly across terminals actually on the magnet M, and arranged permanently in shunt with the magnet. The ohmic resistance of this carbon resistance R is such that only a small current will pass through it when the magnet is normally

Fig. 1.

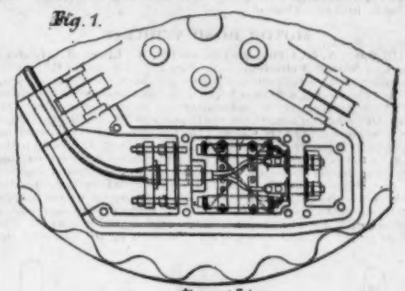
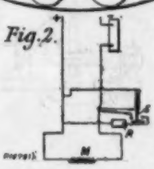


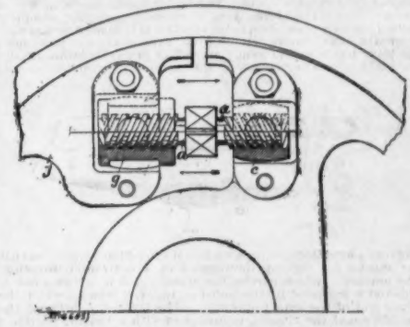
Fig. 2.



connected and operating, but immediately there is a slight rise of voltage across the magnet terminals, the resistance rapidly decreases, due to its negative temperature coefficient, and provides a good damping or discharge path. An alternative method of carrying the invention into effect is illustrated in Fig. 2. In this example, a relatively low resistance R is mounted on the magnet M, together with a potential relay or switch S, which connects the resistance in shunt with the magnet immediately there is a rise of voltage across the magnet terminals, and disconnects the resistance as soon as the voltage again reaches normal. (*Accepted July* 3, 1918.)

MACHINE AND OTHER TOOLS, SHAFTING, &c.

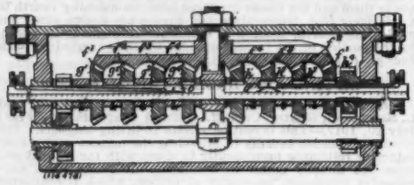
116,683. R. Bridge, Castleton, and J. G. Bradshaw, Castleton. Friction Clutches. (4 *Figs.*) April 20, 1918.—The invention has reference to friction clutches of the well-known Heywood and Bridge type, in which the internal half of the clutch consists of a ring of metal rendered expansible by cuts made across the periphery. The invention relates to means to enable the internal ring to be adjusted to the outer shell to compensate for wear. To effect this, the steel right and left-hand screw threaded spindle *a*, which is rotated by the top lever of the clutch actuating mechanism to put the clutch in and out of gear, is



mounted at one end in a nut *e* capable of oscillating on trunnions, the other end, operating the spring or resilient portion of the ring *j*, engaging with a nut *g*, which normally is clamped to prevent its rotation, the clamping means for the nut also being mounted on trunnions. When adjustment of the spring portion of the internal ring *j* is required, the clamping means for the nut *g* are released and the nut is rotated by suitable means, whereby, according to the direction of rotation of the nut, the spring or resilient part of the internal expansion half of the clutch can be adjusted towards or from the outer shell. (*Accepted June* 26, 1918.)

116,476. T. S. Wilson and S. C. Bone, Garston, Liverpool. Variable-Speed Gear. (5 *Figs.*) February 7, 1918.—This invention relates to variable speed gear of the type which is capable of transmitting varying speeds as well as a reverse motion from the driving part to the driven part, and more particularly to a type of speed gear which suggested the use of bevel gears in constant mesh with a compound gear consisting of a series of concentric bevel gears of different diameters rotating on an axis at right angles to the axis of the bevel gears. The improved variable speed gear consists essentially of two groups of bevel gears *g*1, *g*2, *g*3, *g*4, *h*1, *h*2, *h*3, *h*4 constantly rotating at all the different forward speeds provided and constantly meshing or making contact with a compound gear comprising a series of concentric bevel gears *f*1, *f*2, *f*3, *f*4 of different diameters on an axis

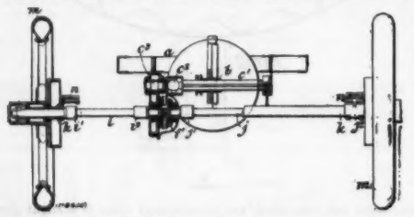
at right angles to the plane of the common axis of the two groups of bevel gears, of which one group (numbering two or more) on one side of the axis of the compound gear transmits or receives through the compound gear a variable rotary motion to or from the second group of bevel gears (numbering two or more) on the



other side of the axis of the compound gear, the several bevel gears in the two groups being mounted loose on their respective shafts or sleeves and being geared thereto or rendered inoperative as required by means of sliding keys o, o^1 controlled by levers or other suitable devices. (*Sealed.*)

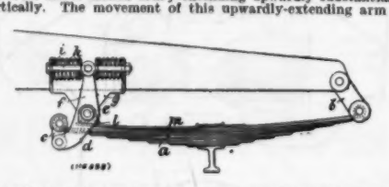
MOTOR ROAD VEHICLES.

116,400. A. G. Grice and G. and V. R., Limited, Maidenhead. Motor Vehicles. (2 *Figs.*) July 26, 1917.—This invention relates to motor vehicles provided with driving gear of the type having a driven friction element connected by speed reduction gearing to the pinion-carrying member of a differential gear, the relatively movable shaft portions of which distribute the power at or about the speed of the road wheels. The invention consists in a power transmission gear as indicated, in which the friction drive, speed reduction and differential gear are carried upon the chassis frame and the road wheels are mounted directly on the ends of the shaft portions of the differential, flexible connections being provided in said portions to accommodate spring mounting on the road wheels. A motor chassis frame *a* is fitted with a variable speed friction transmission gear *b*. The motor power shaft is conveniently situated in the plane of the



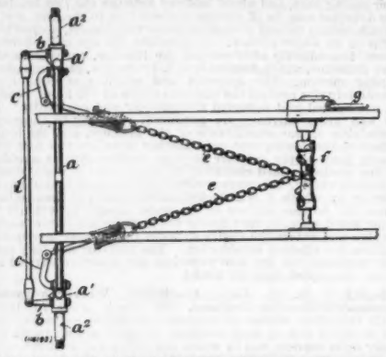
central longitudinal axis of the vehicle, and the axially-movable rim friction wheel *c* is mounted upon a short transverse shaft c^1 carried in bearings rigidly attached to the chassis frame. The shaft c^1 drives through the flexible coupling c^2 a pinion c^3 which, by means of independent and driven gear wheels, transmits the power to the casing or frame member f^1, carrying the intermediate pinions of a differential gear-box *f* also rigidly connected to the chassis frame *a*. The two relatively-movable wheels of the differential gear are mounted upon shaft portions *i* and *j* provided with flexible connections i^1, i^2, and j^1, j^2, said shafts passing through the ends of the hollow axle member *k* and being connected to the hubs of the road driving wheels *m*. The hollow axle member *k* is cranked back and passes transversely across the vehicle, being flexibly connected to the chassis body by means of the springs *n*. (*Accepted June* 19, 1918.)

116,385. The Birmingham and Midland Counties Transport Company, Limited, and G. E. D. Ralls, Birmingham. Spring Suspension Mechanism. (1 *Fig.*) June 9, 1917.—This invention relates to spring suspension mechanism for motor vehicles. A laminated spring *a* is mounted upon the front wheel axle, the front end of which spring *a* has a shackle *b* by which it is coupled to the chassis. The spring *a* is at the rear coupled to a shackle *c* which is coupled to the one arm *d* of a double lever. This lever arm *d* extends upwardly obliquely towards the wheel axle to a point at which it is carried by a pivot *e* secured to the chassis. Beyond its axis of pivotal movement the lever has a second arm *f* extending upwardly substantially vertically. The movement of this upwardly-extending arm is



controlled by coiled springs with axes disposed horizontally so that the shocks are thereby intercepted in a horizontal direction. The bracket *g*, which carries the spindle *e*, also carries a rod *h*. This rod is encircled by the coiled springs *i*, *i*, between which the upper end of the arm *f* operates. The lever *d*, *f*, between the shackle *c* and the chassis, is furnished with a bearing portion *l* with which a part of the spring *a* nearer to the wheel axle than the extremity of the spring to which the shackle *c* is connected, is adapted to engage in the event of the lever being sufficiently displaced against the resistance of the springs *i*. If desired, the spring *a* may be fitted with a leaf spring *m* which normally occupies a position as shown, in contact with the bearing surface *l*. (*Sealed.*)

116,192. Alldays and Onions Pneumatic Engineering Company, Limited, Birmingham, and C. E. Simms, Birmingham, and N. L. Hilton, Birmingham. Steering Mechanism. (4 *Figs.*) August 17, 1917.—The invention relates to steering mechanism for motor-propelled vehicles known as the "Ackermann" steering gear. According to the invention, both stub axles for the front wheels of the vehicle are provided with coupling and steering arms, and the steering arms are connected by means of chains or cables to a drum which is rotated in one or other direction through the operation of the worm and worm wheel gear of the steering mechanism. The drum is so shaped that the requisite differential winding and unwinding of the two chains or cables is ensured. *a* is the front axle having at each end a swivel or stub axle as is usual. The stub axles are pivoted to the ends of the axle *a* by pins passing through lugs a^1, a^1 at the inner ends of the stub axles a^2 and through bearings in the ends of the axle *a*. The lugs a^1, a^1 have fixed to them coupling arms *b*, *b* and steering arms *c*, *c*. The coupling arms *b*, *b* are connected together by the coupling rod *d* as is usual. The steering arms *c*, *c* are connected through chains or cables *e*, *e* with a drum *f* which is shaped so that on the rotation of the same, effected by the usual worm and worm-wheel gear



at the lower end of the inclined steering post *g*, the chains or cables *e*, *e*, will be wound on and payed off the drum *f* to the requisite relative extent to ensure the proper angular motion of the stub axles a^2 and to preserve the chains or cables *e*, *e* taut. (*Sealed.*)

PUMPS.

116,440. The New Rotoplunge Pump Company, Limited, Westminster, C. Lakin-Smith, Westminster, and N. G. Beckwith, Hampton-on-Thames. Rotary Pumps. (6 *Figs.*) October 17, 1917.—This invention relates to improvements in rotary pumps of the form wherein pistons connected together in pairs, which operate in unison, rotate within a casing divided into suction and delivery chambers. The invention consists in rotary pumps of the type described, having its interlacing piston structures of exactly similar form and adapted to be actuated by plane surfaces provided on an eccentrically-mounted block. 1 designates the cylinder body or rotor which is mounted to rotate in a casing 2 divided by the bridges 3 into suction and delivery chambers 4 and 5. The rotor 1 is provided with borings 6, 7 to form cylinders in which the piston structures 8, 9 reciprocate; the boring 6 is slightly staggered or out of plane with the boring 7. The piston structures 8, 9 each consist of a pair of piston heads

Fig. 1.

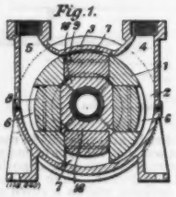
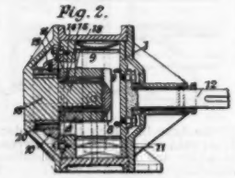


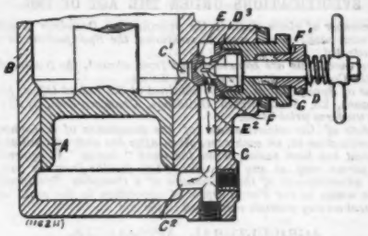
Fig. 2.



joined by a trunk 8a, 9a, and the cylinders are staggered in position relative to each other to the extent of the width of these trunks 8a, 9a. By this arrangement the pistons can be readily assembled in the cylinders since after the one piston is in position the other can be threaded in, the trunks 8a, 9a crossing each other in different planes as will be readily seen upon reference to Fig. 2. The outer casing 2 is closed by end plates 10, 11, one of which, 11, carries the bearing for the driving shaft 12, while the other carries integral with it an eccentric pin 13, and the bearings 14 and 15. A faced block 16 is mounted on the outer bearing 15, the faces of this block co-operating with the pistons 8, 9. The rotor 1 is supported concentrically with the axis of rotation on the boss 18, from which the eccentric pin 13 proceeds, a ring 19 being provided to connect the rotor rigidly to the sleeve 20 which rotates upon the boss 18. At the other side, the rotor 1 is bolted to the driving shaft 12. A feature of the invention of some importance is the provision of a distinct clearance between the periphery of the rotor 1 and the bridges 3, and it will be found in practice that although at impracticably low speed considerable leakage will occur from the delivery to the suction side of the pump by reason of this clearance, at higher and all normal speeds a liquid seal forms and no leakage occurs, while since there is no actual contact between the rotor and the bridges there is no possibility of wear. (*Accepted June* 19, 1918.)

STEAM ENGINES, BOILERS, EVAPORATORS, &c.

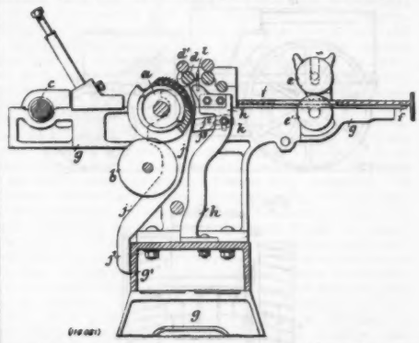
116,211. A. H. Anthony, Colchester. Boiler-Feed Apparatus. (2 Figs.) October 10, 1917.—This invention relates to automatic boiler-feed regulators of the kind in which the flow of feed-water into the boiler past a check valve is controlled by providing the check valve with a balancing or controlling piston from the one end to the other of whose cylinder water leaks by a duct external to the cylinder and the escape of the water that has thus leaked is so automatically controlled as to destroy or restore the balance of the check valve, or otherwise vary the effect of the piston, and thus determine when feed water is to enter the boiler. According to the present invention, an automatic boiler-feed regulator of the kind defined is constructed to have a leakage orifice which is unobstructed, in combination with a closured cleaning aperture therefor provided in the wall of the leakage duct, the said aperture and orifice being so mutually situated that access to the latter is obtainable through the former from without the cylinder. The piston A, constituting the balancing piston for the check valve, works in a cylinder B which is provided with a bleed duct C external to the cylinder cavity and operating as a bye-pass duct from the upper side of the piston to its underside. The main direction of the duct C is parallel to the axis of the cylinder, but it has two branches extending through the cylinder wall to the cylinder cavity, one at C^1 and the other at C^2. The upper portion of the duct is virtually T-shaped by reason of a radially directed outward extension which is in line with the passage C^1. In the extension is screwed a two-part tubular plug D, D^3, of which the inner part D^3 has a valve seating in the passage C^1. The inner end of the plug is pierced with a bleed hole E to constitute the leakage aperture, and the wall of the plug is pierced with openings in register with the portion C of the duct. Within the plug is slidably mounted a cleaning pricker F whose stem passes through a stuffing-box G in the head of the plug. A strong compression spring is mounted between the head of the pricker and the gland of the stuffing-box so as to tend constantly to hold the pricker in the position in which it is shown. The inner portion of the stem of the pricker is reduced in diameter so as not in any position to close the openings E^2 in the plug and just at this point the stem carries a flange which serves to limit the outward travel of the pricker and incidentally to assist in preventing leakage of water past the stem F^1. The leakage takes



place through the aperture E. Accumulation of sediment around the walls of the piston does not, therefore, interfere with the working of the apparatus, and should the aperture E become blocked, partially or completely, it can be immediately cleaned by pushing the pricker F in against the action of its spring. On releasing the pressure, the spring immediately returns the pricker to the position shown. (*Accepted June* 12, 1918.)

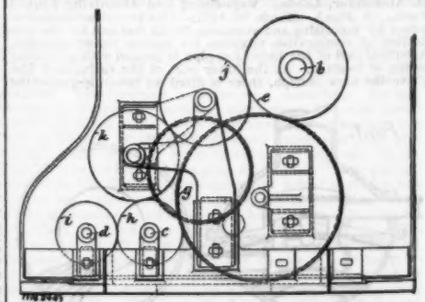
TEXTILE MACHINERY.

116,061. Asa Lees and Company, Limited, Oldham, and J. W. Clegg, Oldham. Combing Machines. (1 *Fig.*) February 27, 1918.—The invention relates to combing machines of the Nasmith type, and consists essentially in mounting a bracket on, or forming an extension of, the stand or frame on each side of the combing machine and supporting the cylinder cover and selvedge guides adjustably therefrom. *a* designates the comb cylinder, *b* the brush, *c* the nipper shaft, *d*, d^1 the detaching rollers, *e*, e^1 the calender rollers, *f* the sliver table, *g* the stand or frame of the machine. For the purpose of this invention, a bracket *h* is mounted on each side of the machine on the stand or frame, and



to each bracket *h* there is bolted or otherwise adjustably secured one of the pair of selvedge guides *i* and also the cylinder cover *j*. The lower end of the cylinder cover *j* is shaped at j^1 to fit and bear against the front of the beam g^1 and near its upper end it is provided with a back fin or projection j^2, slotted at j^3 to receive the bolt *k* by which it is adjustably secured to the bracket *h*. By means of the bolt *k* and slot j^3, or equivalent connection on each side of the machine, the cylinder cover *j* can be readily set and adjusted when required relatively to the cylinder *a*, and by means of the connecting bolts shown, or any suitable equivalents, the selvedge guides *i* can be adjusted on their supporting brackets *h*. (*Sealed.*)

116,244. Asa Lees and Company, Limited, Oldham, and R. Taylor, Oldham. Spinning and Twisting Machines. (3 *Figs.*) February 27, 1918.—This invention relates to speed frames and like spinning and twisting machines of the type in which the spindles are driven by positive gearing. For the purpose of this invention, there is secured adjustably on the driving shaft *b* a spur wheel *e*. Two trains of gears give the ordinary and reverse direction to the spindle driving shaft *c*, *d*, and spindles. When the spur wheel *e* is in gear with the first train consisting of the spur wheel *g* which gears with the spur wheel *h* on the spindle driving shaft *c*, the spur wheel *h* gearing with the spur wheel *i* on the spindle driving shaft *d*, the shafts



c and *d* will be driven, and so through the usual gearing will drive the spindles in the ordinary direction, say, for spinning right hand twist. The second train of gears consists of the spur wheels *j* and *k*, the latter meshing with the spur wheel *h*, consequently when it is required to reverse the direction of rotation of the spindles, all that is necessary is to release the pinching screw which fixes the spur wheel *e* on the shaft *b*, and move the wheel *e* along the driving shaft *b* out of gear with the upper wheel *g* and into gear with the spur wheel *j*, when the spindles will at once be rotated in the reverse direction, to spin the other hand without any other mechanism or motion being effected. (*Accepted June* 12, 1918.)